EP-86 621

(12) UK Patent Application (19) GB (11) 2 336 508 (13) A

(43) Date of A Publication 20.10.1999

(21) Application No 9904575.9

(22) Date of Filing 26.02.1999

(30) Priority Data
(31) 9804640 (32) 04.03.1998 (33) GB
(31) 9804639 (32) 04.03.1998

(71) Applicant(s)
Inmarsat Limited
(Incorporated in the United Kingdom)
99 City Road, LONDON, EC1Y 1AX, United Kingdom

(72) Inventor(s)
Howard Ray Feldman
Siu Wah Wong

(74) Agent and/or Address for Service
R G C Jenkins & Co
26 Caxton Street, LONDON, SW1H ORJ,
United Kingdom

(51) INT CL^6
H04Q 7/32 // H04B 7/185 7/26

(52) UK CL (Edition Q)
H4L LECTP L1H8A

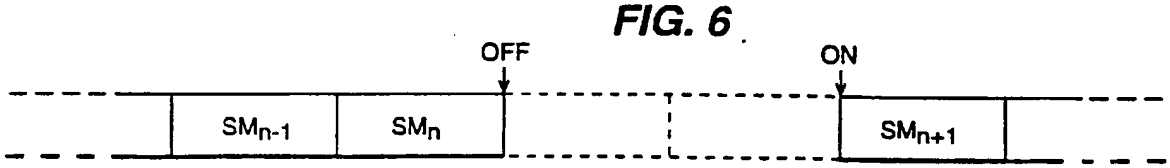
(56) Documents Cited
US 5239557 A

(58) Field of Search
UK CL (Edition Q) **H4L LDGX LDH LDRS LECSV LECSX LECTP LETXX**
INT CL^6 **H03G 3/20 3/30 , H04B 7/005 7/155 7/185 7/212 7/26 , H04Q 7/22 7/32**
Online Databases: WPI, EPODOC, JAPIO

(54) Abstract Title
Data carrier deactivation in absence of user data

(57) In a radio communications system in which data is transmitted on a modulated radio frequency carrier, the carrier is switched off when no data is available for transmission. If repeated signalling information is required to be transmitted, only a predetermined number of repeats are transmitted before the carrier is switched off. In one embodiment a bit sequence at the end of a first data block is compared with multiple sequences from a second block and if all sequences are equal, transmission of the second block is inhibited. In another embodiment data input for transmission is compared with a predetermined bit sequence. If a match is found for any relative bit alignment, this indicates an idle state (absence of user data) and the carrier is switched off. When more user data is received the carrier is switched on and frames are transmitted in synchronisation with the timing of frames transmitted before carrier deactivation. After carrier reactivation a constant power preamble may be transmitted to assist in level control in the transmitter. In a satellite SCPC system satellite power efficiency is improved and mobile earth station battery power is saved.

FIG. 6



GB 2 336 508 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy

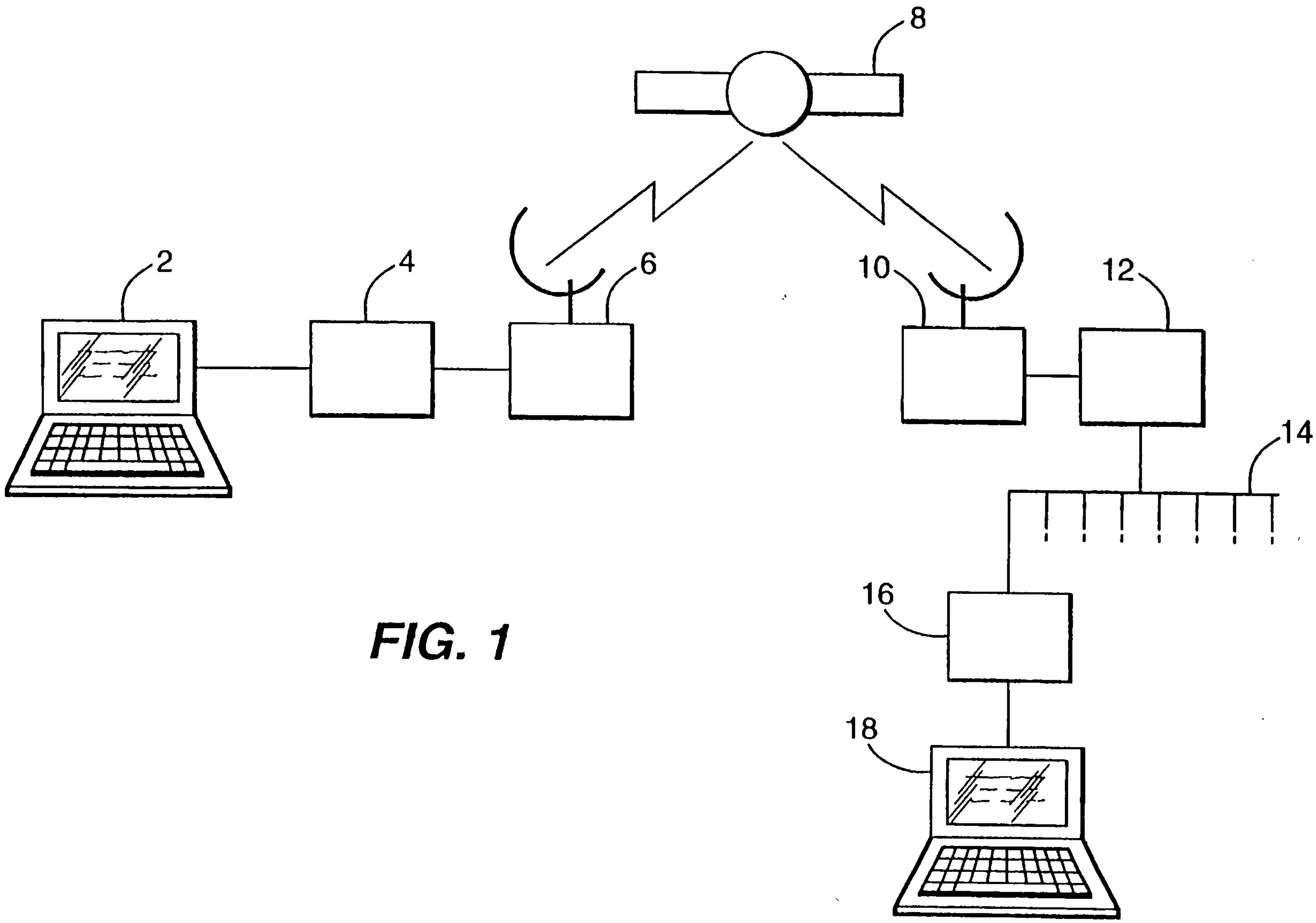


FIG. 1

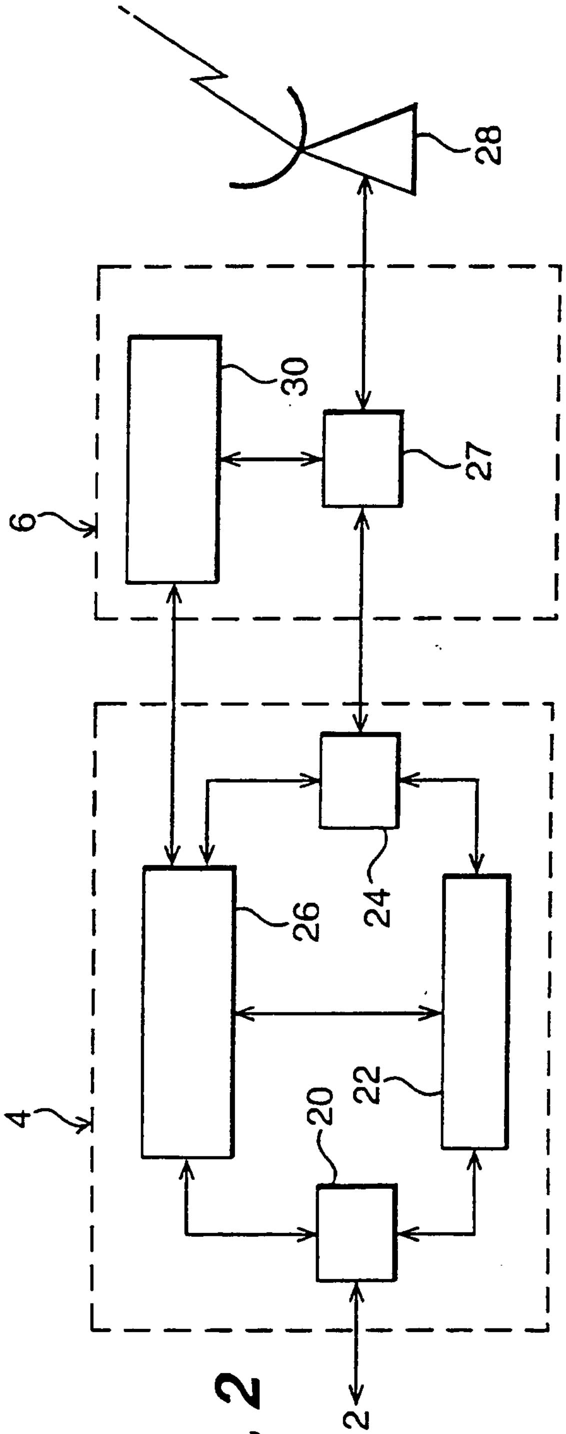


FIG. 2

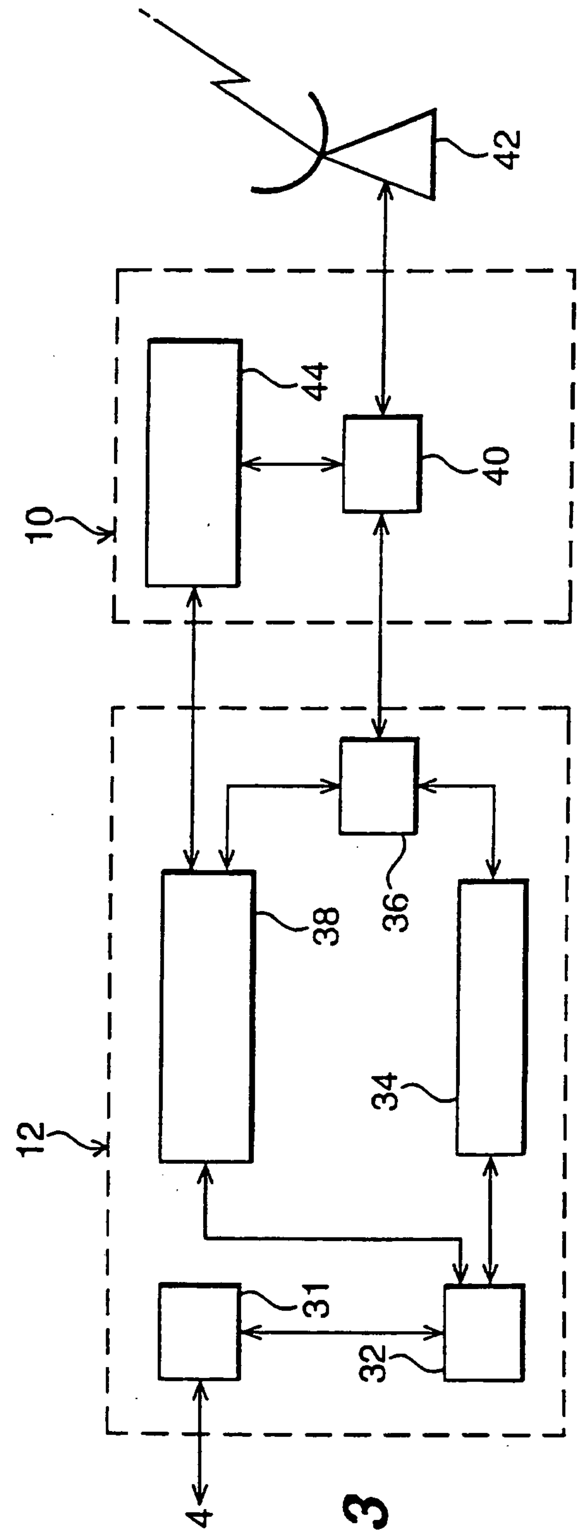


FIG. 3

FIG. 4

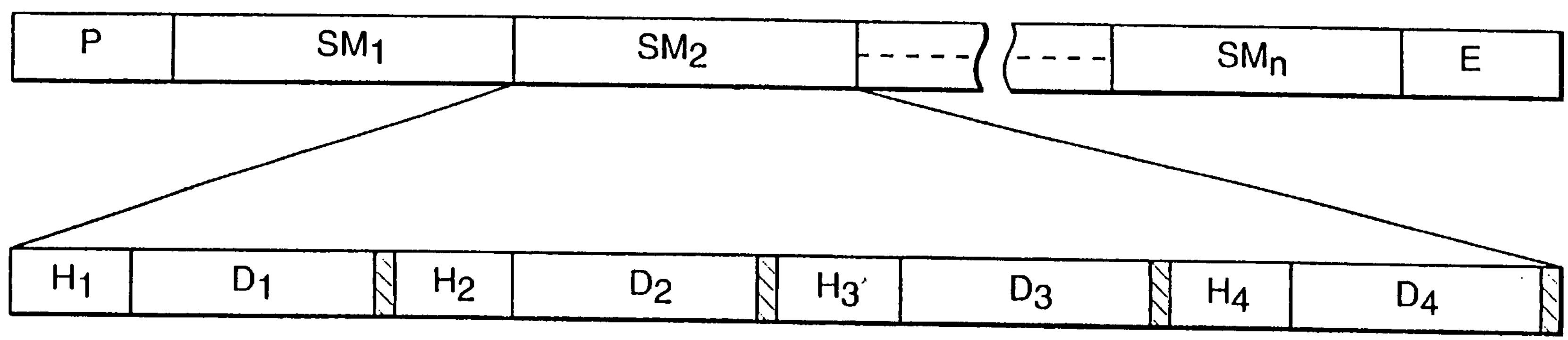


FIG. 6

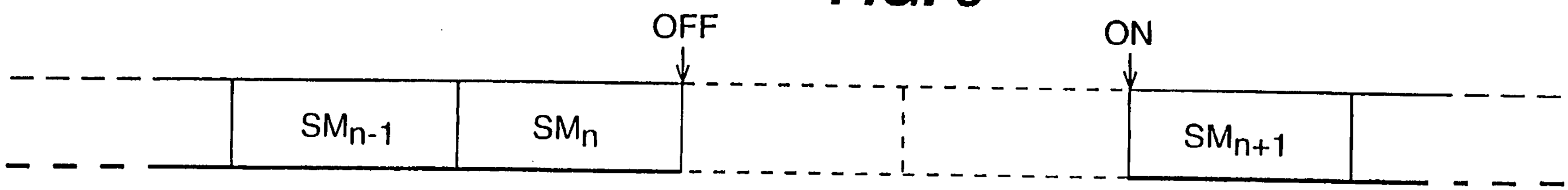


FIG. 10

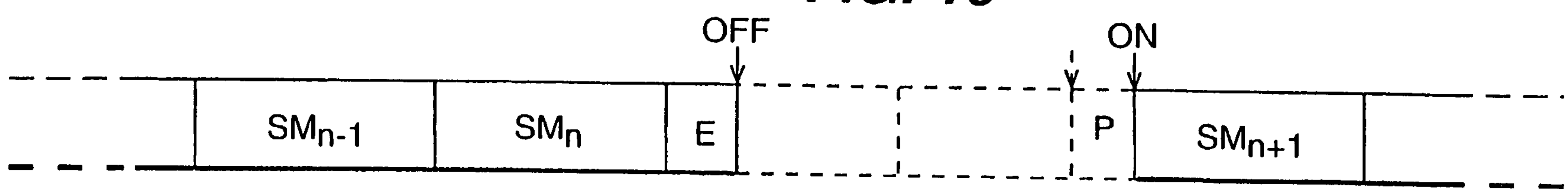


FIG. 5

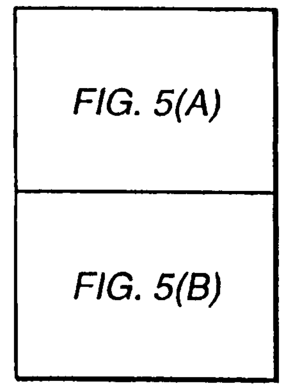


FIG. 7

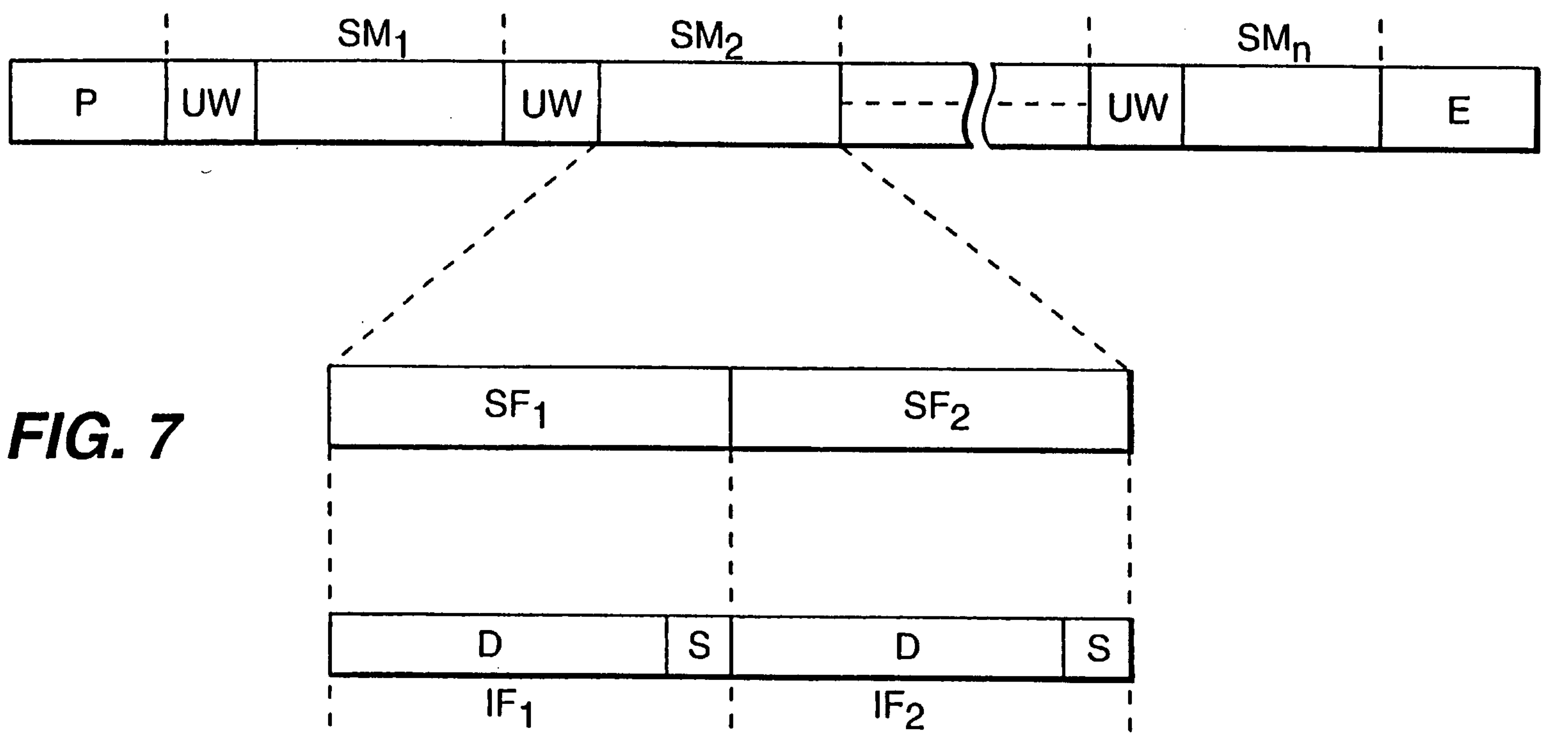
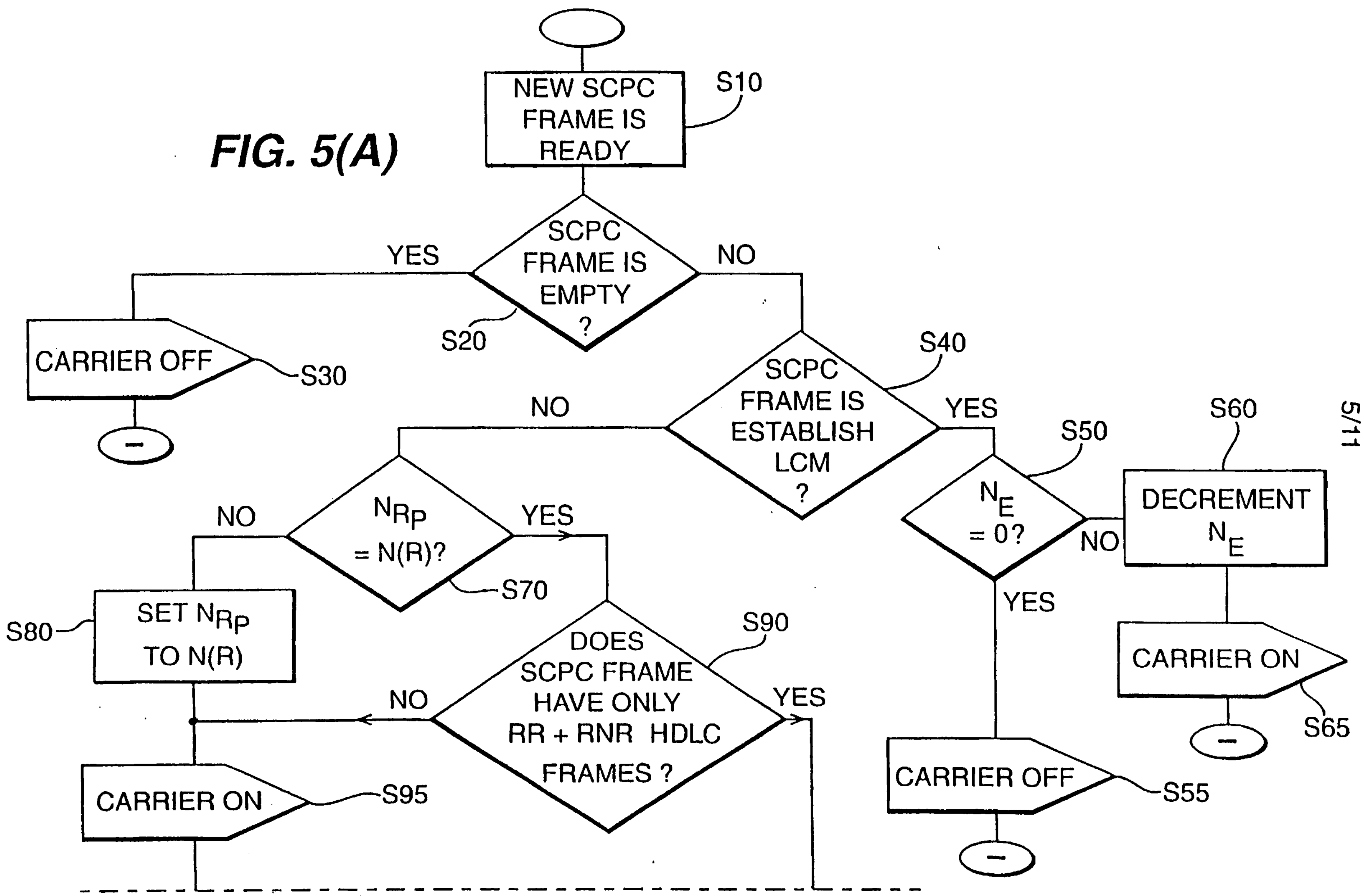
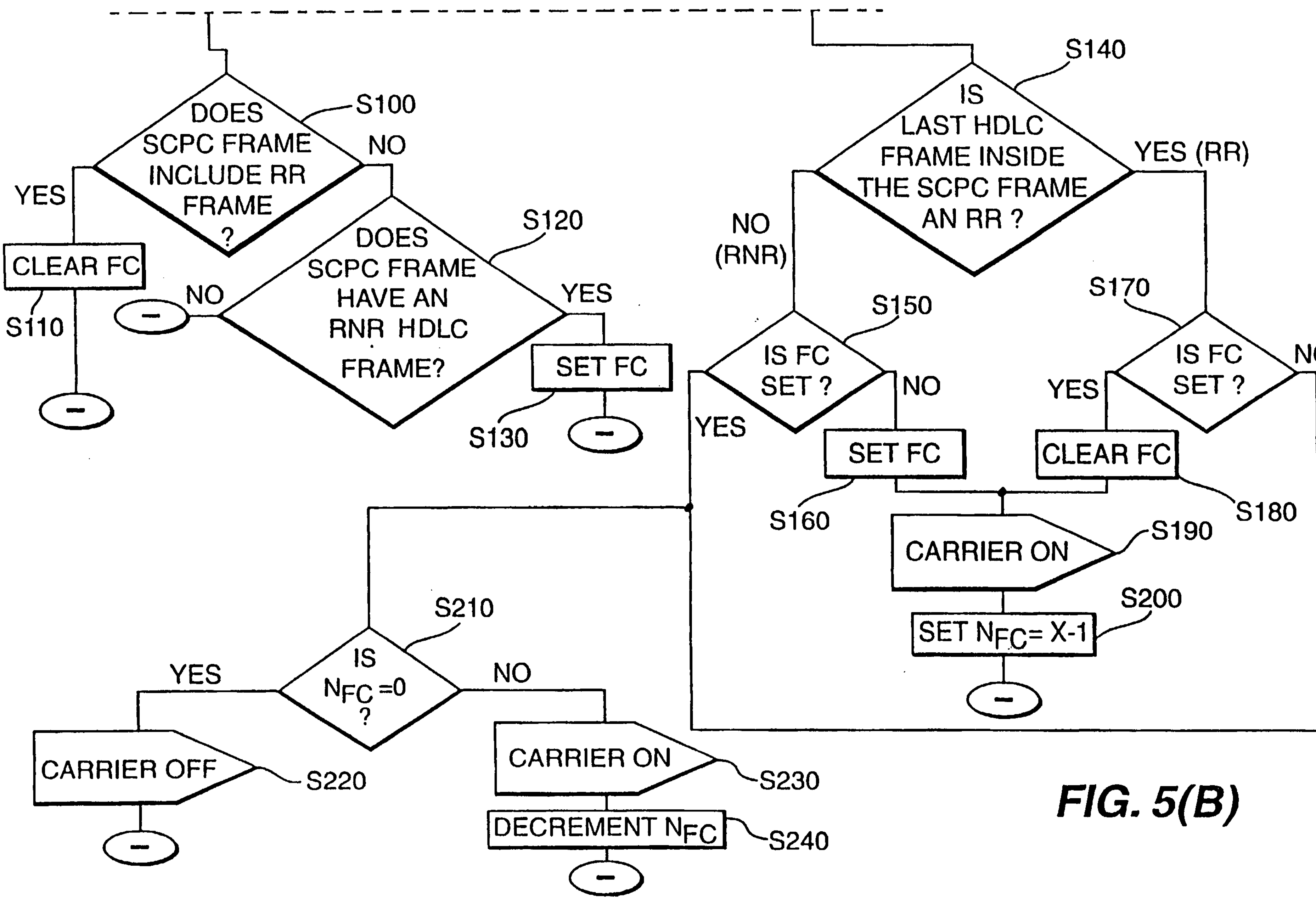


FIG. 5(A)


NEW SCPC FRAME IS READY
S10
SCPC FRAME IS EMPTY ?
S20
YES
NO
CARRIER OFF
S30
SCPC FRAME IS ESTABLISH LCM ?
S40
NO
YES
N_E = 0?
S50
NO
YES
DECREMENT N_E
S60
CARRIER ON
S65
CARRIER OFF
S55
N_{Rp} = N(R)?
S70
NO
YES
SET N_{Rp} TO N(R)
S80
DOES SCPC FRAME HAVE ONLY RR + RNR HDLC FRAMES ?
S90
NO
YES
CARRIER ON
S95



DOES SCPC FRAME INCLUDE RR FRAME ?
S100
YES
NO
CLEAR FC
S110
DOES SCPC FRAME HAVE AN RNR HDLC FRAME?
S120
YES
NO
SET FC
S130
IS LAST HDLC FRAME INSIDE THE SCPC FRAME AN RR ?
S140
YES (RR)
NO (RNR)
IS FC SET ?
S150
YES
NO
SET FC
S160
IS FC SET ?
S170
YES
NO
CLEAR FC
S180
CARRIER ON
S190
SET N FC= X-1
S200
IS N FC =0 ?
S210
YES
NO
CARRIER OFF
S220
CARRIER ON
S230
DECREMENT N FC
S240

FIG. 5(B)

FIG. 8

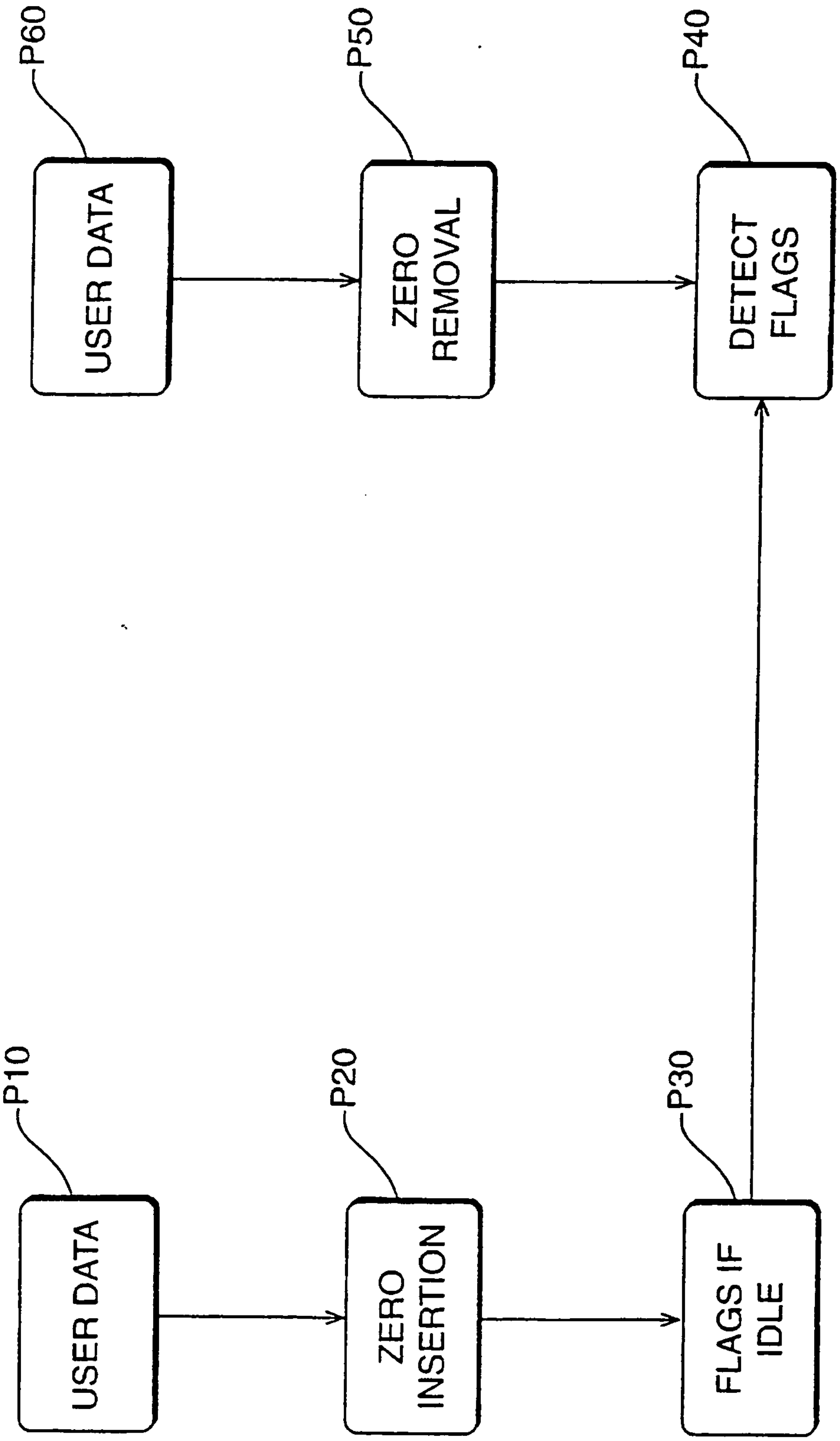

USER DATA
P10
ZERO INSERTION
P20
FLAGS IF IDLE
P30
DETECT FLAGS
P40
ZERO REMOVAL
P50
USER DATA
P60

FIG. 9

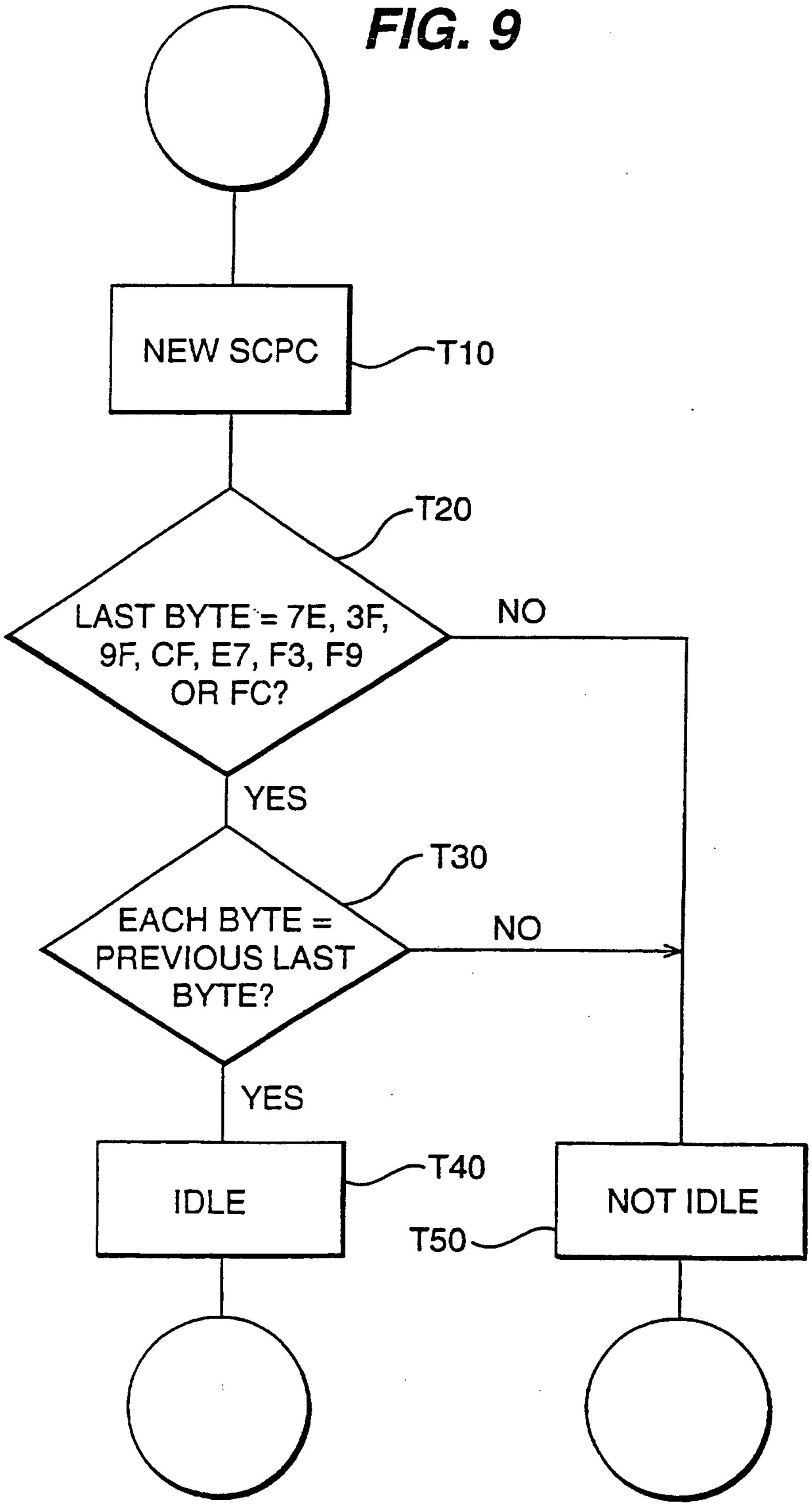
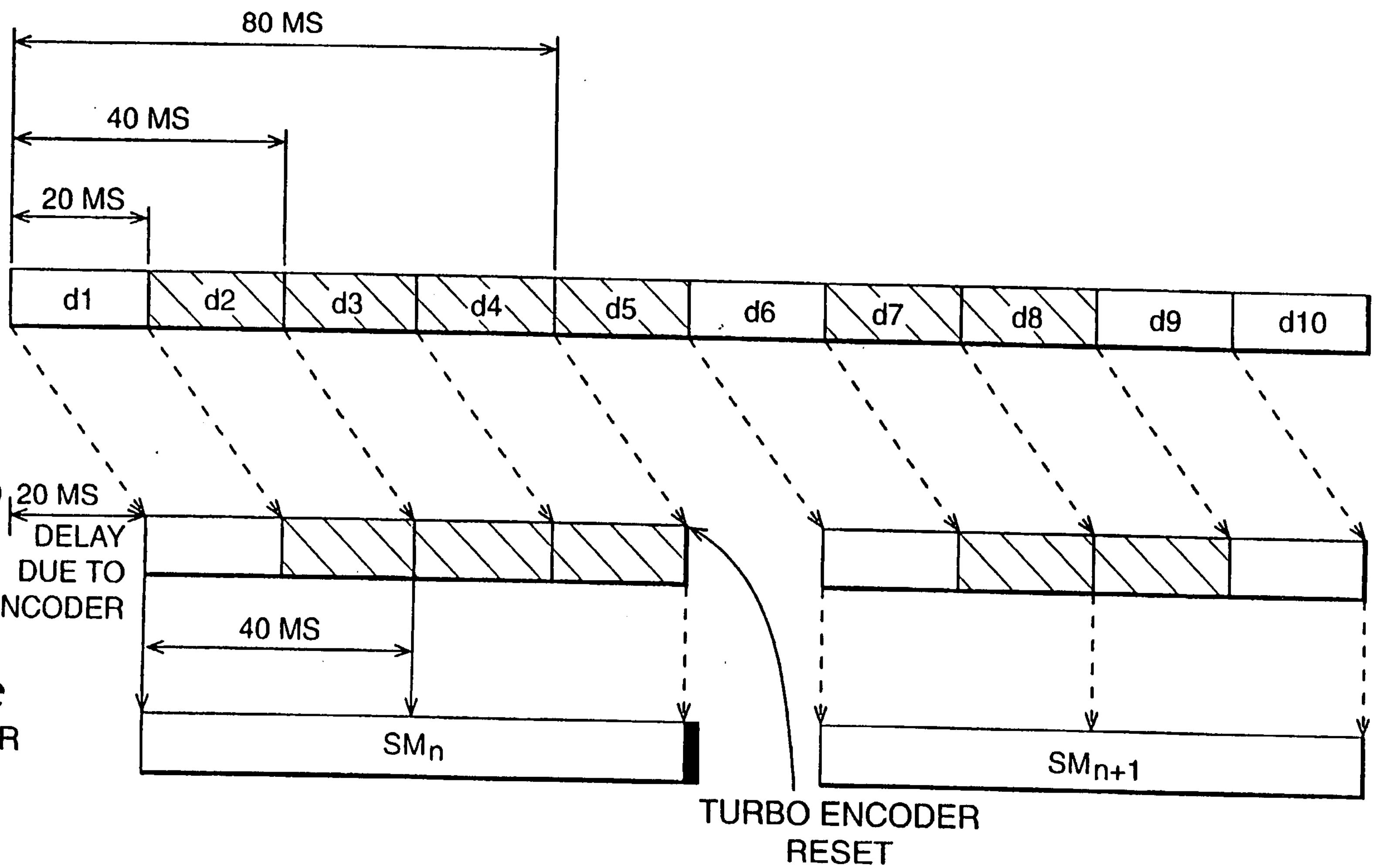

NEW SCPC
T10
T20
LAST BYTE = 7E, 3F, 9F, CF, E7, F3, F9 OR FC?
NO
YES
T30
EACH BYTE = PREVIOUS LAST BYTE?
NO
YES
IDLE
T40
NOT IDLE
T50

FIG. 11a
DATA

FIG. 11b
TURBO ENCODER

FIG. 11c
TRANSMITTER

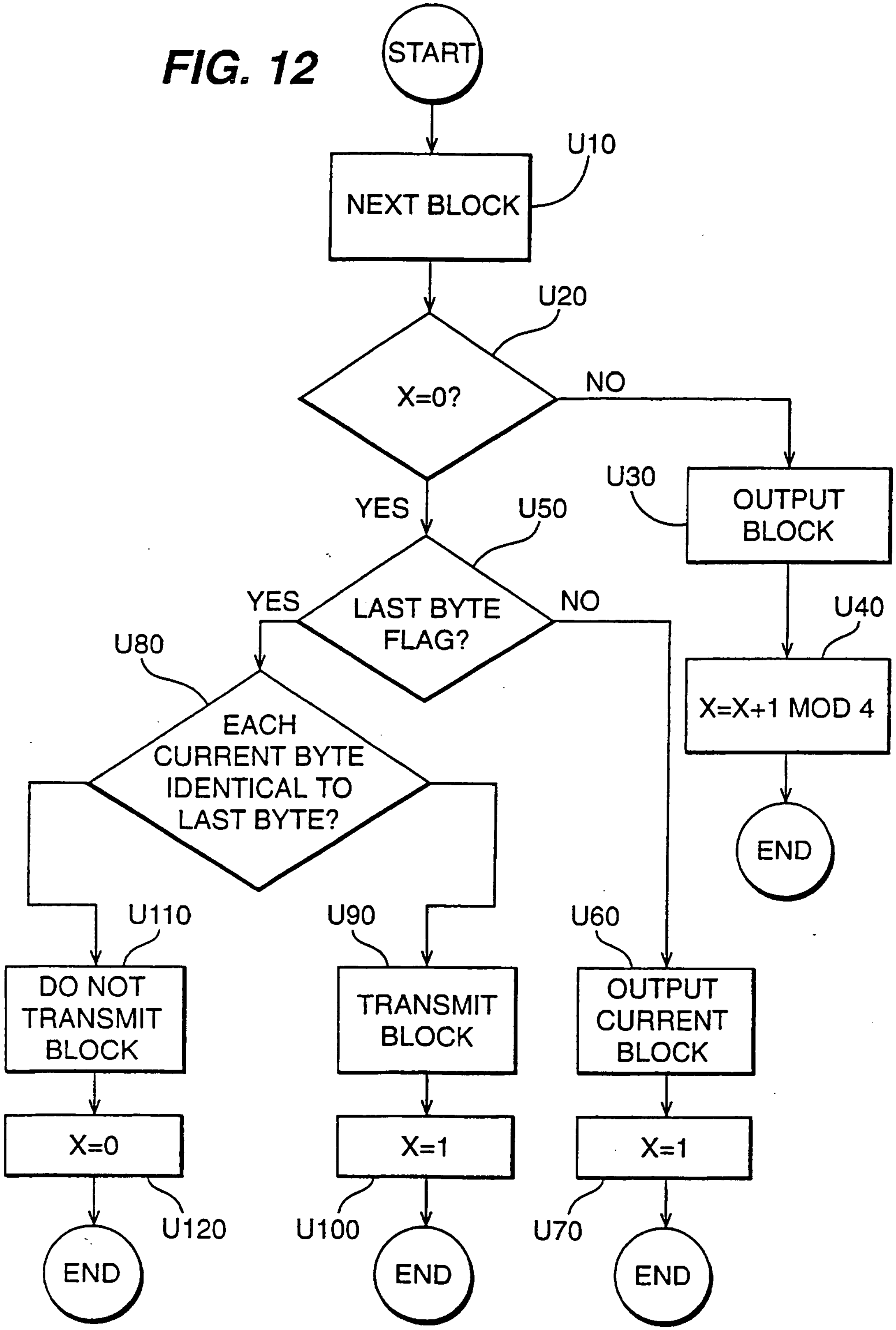


KEY

INTERVAL CONTAINING USER DATA

INTERVAL CONTAINING NO USER DATA

FIG. 12


START
NEXT BLOCK
U10
U20
X=0?
NO
YES
U30
OUTPUT BLOCK
U50
LAST BYTE FLAG?
YES
NO
U40
X=X+1 MOD 4
END
U80
EACH CURRENT BYTE IDENTICAL TO LAST BYTE?
U110
U90
U60
DO NOT TRANSMIT BLOCK
TRANSMIT BLOCK
OUTPUT CURRENT BLOCK
X=0
X=1
X=1
U120
U100
U70
END
END
END

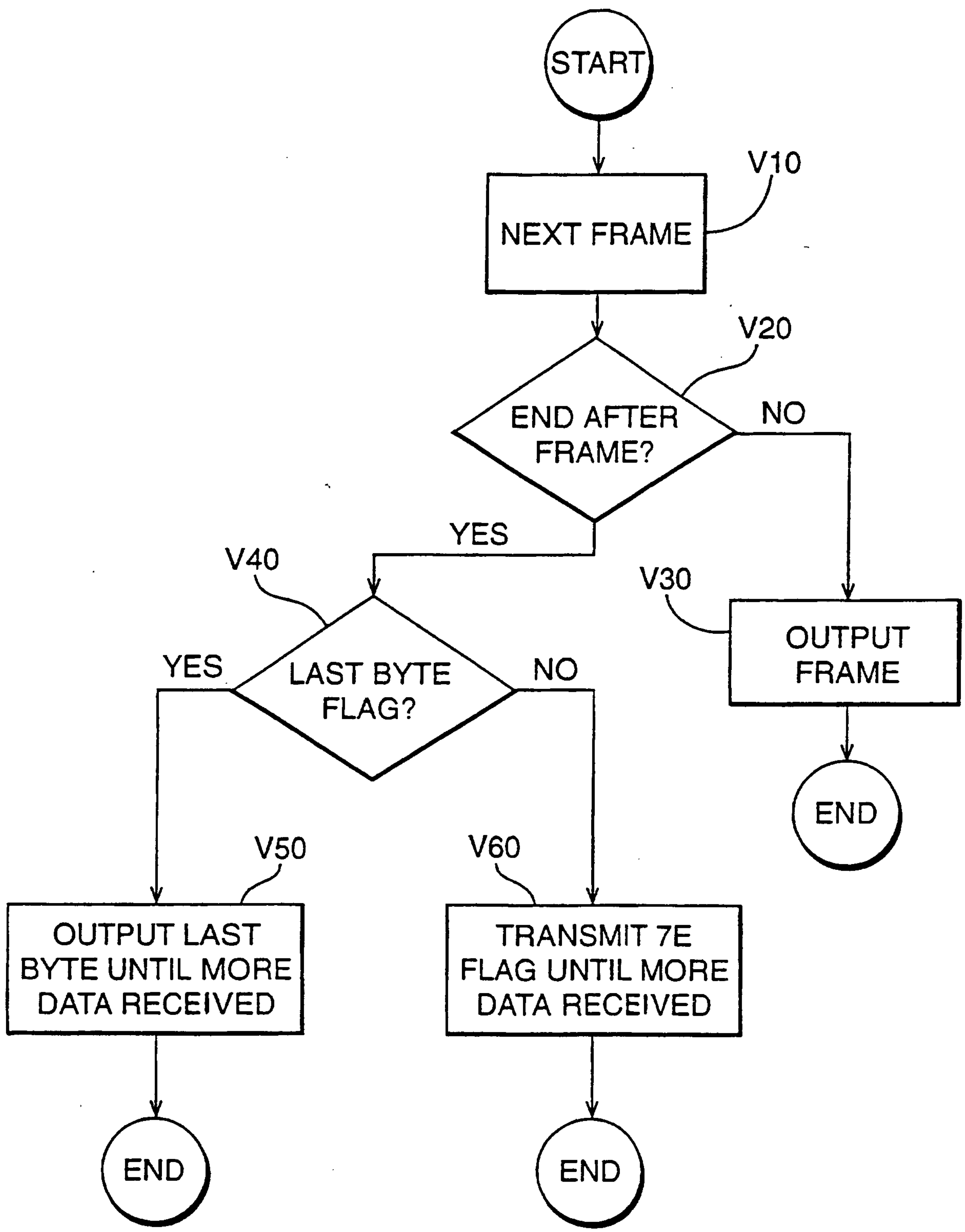

START
NEXT FRAME
V10
V20
END AFTER FRAME?
NO
YES
V30
OUTPUT FRAME
END
V40
LAST BYTE FLAG?
YES
NO
V50
V60
OUTPUT LAST BYTE UNTIL MORE DATA RECEIVED
TRANSMIT 7E FLAG UNTIL MORE DATA RECEIVED
END
END

FIG. 13

CARRIER ACTIVATION FOR DATA COMMUNICATIONS

The present invention relates to a data communication method and apparatus, and in particular such an apparatus for carrier activation in a satellite communication system.

In satellite voice communication systems, it is known to switch the carrier off in one direction over the satellite link when the party transmitting in that direction is not talking. This technique is known as 'voice activation' or more generally 'carrier activation' and is described for example on page 55, section 3.2 of 'Satellite Communications - Principles and Applications' by Calcutt and Tetley, First Edition 1994, published by Edward Arnold. The average English speaker only talks during about 40% of the time during a telephone conversation, and therefore a satellite power saving of up to 4 dB can be achieved by this technique.

The document US 5481561 mentions that carrier activation could be applied to voice, facsimile and data communications, but recognizes that this is difficult to realize in practice.

Carrier activation in fax calls has been implemented in the Inmarsat-M™, Inmarsat-B™ and Inmarsat-mM™ satellite services. The deterministic nature of the ITU T.30 protocols, to which Group 3 fax terminals conform, is used to detect when one terminal is about to receive page data and will therefore not be transmitting; the carrier for transmission by that terminal is then switched off.

However, duplex data calls are generally not considered suitable for carrier activation, because data may be sent continuously in both directions.

According to one aspect of the present invention, there is provided a transmitter in a satellite communications system, which receives input data in a format which may include an idle signal indicating that there is no user data present, compares the input data with a bit pattern corresponding to said idle signal in more than one relative bit alignment, and ceases transmission if a match is found.

An advantage of this aspect is that carrier activation may be implemented even when byte alignment is not preserved between transmitting and receiving applications.

According to another aspect of the present invention, there is provided a transmitter in a satellite communications system which assembles data and signalling information for transmission over the satellite, determines which of said signalling information need be transmitted in order to maintain the communications link over the satellite and ceases transmission if there is no data and only unnecessary signalling information to be transmitted.

According to another aspect of the present invention, there is provided a single channel per carrier satellite communications system in which signals are transmitted in a constant length frame structure and carrier activation is implemented such that frames transmitted after reactivation of the carrier are synchronised with the frame timing of frames transmitted before the

deactivation of the carrier. The interval between transmission of frames may be an integral number of frame periods, or an integral number of fractions of a frame period, such as quarters of a frame period.

An advantage of this aspect of the invention is that a receiver may receive and decode the frames transmitted after the reactivation of the carrier without having to reacquire the frame timing. Furthermore, carrier activation may be implemented in this way as an additional feature to an existing satellite SCPC system without modification of frame formatting protocols.

According to another aspect of the present invention, there is provided a method and apparatus of inhibiting transmission of a block of repeated data by detecting whether the last byte of a previous block is the same as each byte of the current block and inhibiting transmission of the current block if this is the case. Preferably, the carrier on which the blocks are transmitted is deactivated or reduced in power during the period in which the current block would otherwise be transmitted.

According to another aspect of the present invention, there is provided a method of transmitting a burst of information after a period of carrier deactivation, in which a constant power level preamble is transmitted before the information. Advantageously, this assists in automatic level control of the transmitter.

Specific embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a diagram of a communications link between data terminals through a PSTN and a satellite network;

Figure 2 is a functional block diagram of a mobile earth station and its associated interface to a data terminal;

Figure 3 is a functional block diagram of a fixed earth station and its associated interface to a PSTN;

Figure 4 shows the channel format used over the satellite link in a first embodiment of the present invention;

Figure 5 is a flowchart of a carrier activation algorithm in the first embodiment;

Figure 6 shows the timing of SCPC frames in the first embodiment;

Figure 7 is a diagram of the frame format used over the satellite link in a second embodiment;

Figure 8 shows an HDLC transmission and reception process including zero insertion and removal;

Figure 9 is a flowchart of a carrier activation algorithm in the second embodiment;

Figure 10 shows the timing of SCPC frames in the second embodiment;

Figures 11a to 11c shows the timing of SCPC frames and the contents of encoded blocks transmitted in those frames, in a third embodiment;

Figure 12 is a flowchart of an algorithm performed by the transmitting MIU on each data block in the third embodiment; and

Figure 13 is a flowchart of an algorithm performed by the receiving MIU in the third embodiment.

The overall layout of a satellite communications system, when used for data communications, is shown in Figure 1. One example of such a system is the INMARSAT-B (TM) or INMARSAT-M (TM) satellite communications system, as described for example in Chapters 12 and 14 of "Satellite Communications: Principles and Applications" by Calcutt and Tetley, 1st edition, published by Edward Arnold. The following system is also described in WO96/31040, the contents of which are incorporated herein by reference.

A mobile DTE 2 is connected via an RS232C interface to a modem interface unit (MIU) 4. The MIU 4 simulates a Hayes - compatible modem and is able to decode Hayes-type commands from the mobile DTE 2, so that off-the-shelf communications software may be used in the mobile DTE 2. The MIU 4 does not perform modulation or demodulation in this case, since it is not connected to an analog line. Instead, the MIU 4 provides an interface to a mobile earth station (MES) 6 which allows communication via a satellite 8 to a fixed or land earth station (LES) 10. The LES 10 is connected to an LES MIU 12 which interfaces the satellite link to a network 14, in this case a public switched telephone network (PSTN), and functions as a modem to convert analog signals on the PSTN 14 to digital signals on the satellite link,

and vice versa. A fixed DTE 18 is connected to the PSTN 14 through a modem 16 of standard type.

Figure 2 shows the MES MIU 4 and the MES 6 in greater detail. The MES MIU 4 comprises a DTE interface 20, which provides an RS232 physical interface and emulates an AT.PCCA type modem, i.e. it complies with the minimum functional specification for data transmission systems published by the Portable Computer and Communications Association (PCCA), including the use of the AT command set and responses.

Data received by the DTE interface 20 is sent to a buffer 22, which is in turn connected to an MES interface 24. The MES interface 24 implements, in ARQ (automatic repeat request) mode, a variant of the HDLC (High Level Data Link Control) protocol, as defined in ISO recommendations ISO/IEC 3309, ISO/IEC 4335: 1993 and ISO/IEC 7809: 1993. The particular version employed is ISO HDLC BAC 3.2, 4, 8, 10, 12 as defined in ISO 7809: 1993 (synchronous, two-way simultaneous, duplex, non-switched). A controller 26 controls the operation of the interfaces 20 and 24 and the flow of data through the buffer 22.

The MES includes an RF modulator/demodulator 27, connected to an antenna 28, for RF modulating the output of the MES interface 24 and transmitting the output through the antenna 28 to the satellite 8, and for RF demodulating RF signals received from the satellite 8 through the antenna 28 and sending the demodulated signals to the MES interface 24. The MES 6

also includes access control and signalling equipment (ACSE) 30, for setting up and clearing the satellite link, which exchanges data with the controller 26 of the mobile MIU 4.

The MES ACSE 30 communicates with a network control station (NCS) which allocates communications channels, supervises communications traffic through the satellite 8 and communicates with further ACSE at the LES.

The mobile MIU 4, MES 6 and ACSE 30 may be integrated in a mobile unit and the antenna 28 may be integrated or connected externally with the mobile unit.

Figure 3 shows the LES 10 and the LES MIU 12 in greater detail. The LES MIU 12 includes a modem 31 for demodulating analog signals from the PSTN 14 and modulating digital signals for the PSTN 14, and a modem interface 32 which supports modem protocols such as V.42 error correction, for communication with the modem 16.

The modem interface 32 is connected through a buffer 34 to an LES interface 36, which implements protocols compatible with the MES interface 24, so that data can be exchanged between the LES MIU 12 and the MES MIU 4. A controller 38 supervises the operation of the modem interface 32, buffer 34 and LES interface 36. The LES interface 36 is connected to an RF modulator/demodulator 40 which modulates signals for transmission to the satellite 8 through an antenna 42, and demodulates signals received from the

satellite 8 though the antenna 42. Call set-up and clearing are controlled by an LES ACSE 44 within the LES 10 which exchanges signals with the LES MIU 12, the MES ACSE 30, and the network control station (NCS).

Although the system described above allows full duplex data communications, many user applications such as file transfer, database and e-mail protocols communicate in half-duplex mode for reasons of design simplicity, even if files are to be sent in both directions. However, switching off the carrier during a call may cause the receiver to lose synchronisation with the transmitter.

Moreover, in existing satellite communications protocols, some redundant signalling takes place when there is no user data to be sent. The carrier could be switched off during this signalling, but it must be determined which signalling is redundant and which is necessary.

In the first embodiment, the MIU connected to both the LES 10 and MES 6 detects whether there is no information or only redundant information to be transmitted, and if so, sends a signal to the LES 10 or MES 6, which disables the transmitter thereof until the MIU indicates that information is ready for transmission. In the case where the LES 10 is receiving the carrier which is deactivated, the LES 10 signals this to the LES MIU 12, which maintains the connection with the PSTN modem 16. For example, if the V.42 protocol is being used, the LES MIU 12 transmits flags.

As described above, the MIU formats the data to be transmitted into HDLC frames. Multiple HDLC frames are formatted into one single channel per carrier (SCPC) frame, as shown in Figure 4. The transmission begins with a header portion P, followed by a sequence of fixed-length SCPC frames SM_1, SM_2, ... SM_n. The end of the transmission is indicated by an end signal E.

Each SCPC frame SM is subdivided into four sections, each containing a header H_1, H_2, H_3, H_4, a data field D_1, D_2, D_3, D_4, and dummy bits (shaded). The data fields D_1 and D_2 together form one or more HDLC frame, which is repeated in the data fields D_3 and D_4, to increase the energy per bit. The contents of each HDLC frame depend on whether data or control information is being sent.

If data is being sent, the HDLC frame has an information (I) format formed from the concatenated data fields D_1 and D_2. The HDLC frame includes control bytes C containing acknowledgement and frame number information indicating the sequence number of the transmitted frame and the sequence number of the last frame received correctly.

Line control messages are sent as unnumbered information (UI) HDLC frames, more than one of which may be contained within the data fields D1 and D2. Flow control messages are sent in a supervisory (S) HDLC frame format.

The LES MIU 12 and the MES MIU 4 are programmed to generate either RR (Receive Ready) or RNR (Receive Not Ready) HDLC flow control

frames when no user data is received and no other HDLC signalling is required. The flow control frames indicate whether the MIU is ready to receive more data over the satellite link. In order to maintain this function, while implementing carrier activation, the MIU follows the algorithm shown in Figure 5. The algorithm is intended as a modification of an existing MIU functionality and is therefore applied after the framing of data into HDLC and SCPC frames, including the generation of RR and RNR frames. The algorithm determines the carrier state which is signalled to the earth station to which the MIU is connected, in order to switch off the carrier.

At the first iteration of the algorithm, at the beginning of a call, initial values of variables are set as follows:

Flow control flag, FC = cleared

Number of redundant flow control frames to be sent, X = 1 (or a higher integer)

Number of 'Establish LCM' to be sent, $N_E = 3$ (or another positive integer)

Variable for detecting change in N(R), $N_{rp} = 0$.

At step S10, it is detected whether a new SCPC frame has been composed. At step S20, it is detected whether the SCPC frame is empty. If so, the carrier state is set as 'OFF' (S30) and the algorithm restarts.

If the SCPC frame is not empty, the MIU detects (S40) whether the new SCPC frame is an 'Establish LCM' (line control message) which is

transmitted during call set-up to establish the parameters of the call. If so (S50), the MIU sets the carrier state as 'OFF' (S55) if the counter N_E (number of Establish LCM) is zero; if N_E is not zero, it is decremented (S60) and the carrier state is set 'ON' (S65). In either case, the algorithm restarts. As a result, sufficient 'Establish LCM' frames are transmitted to ensure that one is received, before the carrier is deactivated.

If the SCPC frame is not an 'Establish LCM', the MIU next detects (S70) whether $N_{rp} = N(R)$, where N(R) is a variable defined in the HDLC protocol and represents the serial number of the next expected I (information) frame. If the current SCPC frames contains more than one HDLC frame each having an N(R) value, the most advanced N(R) value is taken. If $N_{rp} \neq N(R)$, N_{rp} is set to N(R) (S80), the carrier state is set as 'ON' (S95) and the algorithm proceeds to step S100.

If $N_{rp} = N(R)$, the MIU detects (S90) whether the SCPC frame contains only RNR or RR HDLC frames. If not, the carrier state is set as 'ON' (S95) and the algorithm proceeds to step S100. At step S100, the MIU detects whether the SCPC frame includes an RR frame. If so, the flow control flag FC is cleared (step S110) and the algorithm restarts. If not, the MIU detects (S120) whether the SCPC frame includes an RNR frame and sets the FC flag (S130) if it does. In either case, the algorithm then restarts.

If the MIU detects at step 90 that the SCPC frame does contain only RR or RNR frames, this means that no user data is present, but the MIU must

still determine whether the RR or RNR frames need to be sent to ensure flow control. At step 140, the MIU determines whether the last frame inside the HDLC frame is an RR or an RNR frame. If the frame is RNR, the MIU detects (S150) whether FC is set and if not, sets it (S160) and proceeds to step 190. If the frame is RR, the MIU detects whether FC is set, and if so, clears it (S180) and proceeds to step 190.

At step 190, the carrier state is set as 'ON'. The variable N_{FC}, which is used as a counter of the number of redundant flow control indications remaining to be sent, is set (S200) to X-1, and the algorithm restarts.

If FC is detected as set at step S150 or as clear at step 170, the MIU then detects (S210) whether N_{FC} is zero, i.e. whether no more flow control indications need to be sent. If so, the carrier state is set to 'OFF' (S220) and the algorithm restarts. If not, the carrier state is set to 'ON' (S230), N_{FC} is decremented (S240) and the algorithm restarts.

The state of the carrier is redetermined for each SCPC frame and a decision is made as to whether to switch the carrier off for that SCPC frame. The SCPC frame length is constant. Thus, when the carrier is switched off and then on, the next SCPC frame timing is aligned with that of the previous transmitted frame, as shown in Figure 6. In other words, the period for which the carrier is switched off is an integral number of SCPC frames.

A second embodiment of the present invention will now be described, in which a 64 kbit/s channel is provided by the satellite link and is used by an

ISDN application. In this embodiment, the network 14 is an ISDN and the satellite 8 has a multibeam user antenna for communication with the MES 6, in order to increase the gain of the user link and support a higher data rate. In this embodiment the LES MIU 12 provides an ISDN interface to the network 14, while the MES MIU 4 simulates an ISDN terminal adapter for the mobile DTE 2. Since the MES MIU 4 does not simulate a modem in this embodiment, it does not decode the Hayes™ AT command set and is preferably integrated with the MES 6. In the second embodiment, a 16 QAM modulation scheme is used for transmission, such that transmitted data has a variable power envelope. Further details of the modulation and coding schemes are described in co-pending application GB 9804639.4, the contents of which are incorporated by reference in so far as they relate to a 64 kbit/s satellite channel.

As shown in Figure 7, the format used for data transmission in this embodiment comprises SCPC frames SM_1, SM_2 ... SM_n each having as a header a unique word UW to assist synchronisation in the receiver. The end of a sequence of SCPC frames is indicated by an end of data signal E. Each SCPC frame contains two subframes SF1 and SF2. Each subframe SF is encoded from an input frame IF1, IF2 which contains a data field D of fixed length (in this case 2560 bits) and a signalling field S. Each data field D contains HDLC frames transmitted by an ISDN application on the mobile DTE 2 or the fixed DTE 18.

In ISDN applications, an idle state is indicated by transmitting a continuous sequence of HDLC flags (binary 01111110 or hex 7E). However, user data may coincidentally contain this bit sequence. Therefore, the applications follow a procedure as shown in Figure 8. At P10, the user data is assembled for transmission. At P20, any sequence of 5 set bits together (11111) is detected and a zero (0) is inserted after them. The following bits are all shifted one bit position to allow the zero to be inserted. This technique is known as 'zero insertion'. As a result, the user data cannot replicate the flag sequence. At P30, HDLC flags are generated if there is no user data to send and the HDLC frames are transmitted.

At P40, the HDLC frames are received by the receiving application, flags are detected and the user data is separated from them. At P50, a zero is removed after every set of 5 sequential set bits, in a reverse operation to that of P20, to restore the user data to its original form for input to the application at P60.

The user data is formatted in 8-bit bytes and the data field D comprises an integral number of bytes (320 in this case). However, zero insertion destroys the original byte alignment of the user data, so that HDLC flags may no longer appear as binary 01111110. Instead, the HDLC flags may appear as any of the following bytes shown in Table 1:

Table 1

HDLC Flag Representation with Bit Shift

Number of Bits Shifted	Binary	Hex
0	01111110	7E
1	00111111	3F
2	10011111	9F
3	11001111	CF
4	11100111	E7
5	11110011	F3
6	11111001	F9
7	11111100	FC

In this embodiment, the MIU performs the algorithm shown in Figure 9 in order to detect an SCPC frame consisting entirely of flags, which therefore need not be transmitted. At step T10, the MIU assembles the data content of the input frames IF1 and IF2 of the current SCPC frame. At step T20, the MIU checks whether the value of the last data byte of the preceding SCPC frame had any of the hex values shown in Table 1 above. If so, the MIU then detects (T30) whether all of the data bytes in the current SCPC frame are equal to the last data byte of the preceding SCPC frame. If so, this indicates that the entire current SCPC frame consists of HDLC flags and an 'idle' state is set (T40). If either of the tests of T30 and T40 are not satisfied, the 'idle' state is not set (T50).

If the 'idle' state is set, the MIU controls the MES 6 or LES 10 to which it is connected to switch off the carrier for the duration of the current SCPC frame. When a transition occurs to the 'idle' state, the MIU appends an end signal E to the end of the last transmitted SCPC frame, as shown in Figure 10. Subsequently, when a transition out of the 'idle' state occurs, the new SCPC frames are transmitted with the same frame timing as the previously transmitted SCPC frames, so that the start of the new SCPC frame occurs an integral number of frame periods after the start of the previously transmitted SCPC frame.

The receiving MIU, on detecting the end signal E without an indication from the ACSE that the call has been cleared, determines that the transmitting MIU has detected an idle state. Since ISDN is a synchronous protocol, the receiving MIU must continue to transmit signals to its associated DTE. The receiving MIU repeats the last byte of the SCPC frame received before the end signal. Since this has previously been detected by the transmitting MIU to be an HDLC flag or a bit-shifted version thereof, the repeated bytes will be detected as HDLC flags by the receiving user application.

In an alternative to the second embodiment, the MIU continuously checks the input user data without waiting for sufficient user data to be received to form a complete SCPC frame, and an idle state is detected as soon as any 8 consecutive bits have the binary value '0111110', for example by

reading the input bits into an 8-bit shift register and continuously comparing the contents with hex 7E. However, the transmission of the current SCPC frame cannot be interrupted immediately when a flag is detected without violating the frame format, so this option does not confer any advantage in implementing carrier activation and requires a greater processing overhead than the second embodiment.

An optional feature of the frame format of Figure 10 is shown in dotted outline. In this arrangement, a short preamble P is transmitted at the beginning of a burst of frames SM, as soon as the carrier has been reactivated.

The preamble P comprises a repeated sequence of the same 16 QAM symbol, having a power level equal to the average power level of the 16 QAM constellation. The sequence comprises 16 symbols transmitted at a rate of 33.6 kSymbol/s, having a total duration of 476 μs.

The transmission of the preamble assists in automatic level control using a feedback loop in a high-power amplifier (HPA) in the MES RF modulator 27 and the LES RF modulator 40, so that the transmit power can be ramped up to the required level in 500 μs or less.

If the preamble P were not transmitted at the beginning of each burst, the transmission would begin with a unique word which does not have a constant power level, and would then not allow the HPA level to stabilise in the required time.

In another alternative to the second embodiment, when the carrier is switched off and new user data is input to the MIU, the next SCPC frame is transmitted as soon as sufficient data has been received for one subframe SF and that subframe has been encoded. Thus, the previous frame timing is lost and the receiver must acquire the new timing by detecting the unique word UW.

In a third embodiment illustrated with reference to Figures 11 to 13, the MIU divides the baseband data for transmission into blocks d1 to dn each equivalent to 20 ms duration, shown in Figure 11a. The blocks containing no user data are shaded. Each frame SM is of duration 80 ms and so contains four blocks. The MIU performs a carrier activation algorithm as shown in Figure 12 on each block, prior to scrambling and encoding the data for transmission. As described in GB9804639.4, the coding is performed by a Turbo encoder including an interleaver into which one 20 ms block is loaded at a time. The Turbo encoder is reset every 40 ms so that the Turbo encoding algorithm is performed on 40 ms blocks corresponding to two 20 ms blocks or one subframe SF. Because the interleaver has a constraint length of half the total interleaver size, the Turbo encoder incurs only a 20 ms delay as shown in Figure 11a. This technique is described in more detail in PCT/GB97/03551. Hence, the 20 ms blocks are convenient subdivisions of a whole frame on which to perform carrier activation detection.

At step U10, the MIU starts processing the next 20 ms block d. At step U20 the MIU detects whether the block is the first block in a frame SM. A position pointer X counts the position of the current block within the frame, so that at step U20, the MIU detects whether X=0. If X is not zero, this indicates that a previous block in the current frame has already been sent for transmission. Because the MIU cannot interrupt a frame SM once transmission has begun, the current block is then output for scrambling and encoding at step U30 and the counter X is incremented modulo 4 at step U40, to indicate the frame position of the next block to be checked.

If X is zero, indicating that the block, if transmitted, will be first block of a frame, then the MIU detects at step U50 whether the last byte of the previous block was equal to hex 7E, 3F, 9F, CF, E7, F3, F9, or FC. If not, this indicates that idle flags may not be present in the current block and the current block is output for transmission, at step U60. At step U70, X is set to 1, indicating that the next block will be the second block in the frame.

If, on the other hand, the result of the test at step U50 is positive, the MIU detects at step U80 whether each byte of the current block is identical to the last byte of the previous block, as detected at step U50. If not, this indicates that the current block probably contains at least some data other than flags, so the data is output for transmission at step U90, and X is set to 1 at step U100. Otherwise, if the result of the test at step U80 is positive, the current block is not output for transmission at step U110, the carrier is turned

off, and X is set to zero at step U120. As shown in Figure 11b, the 20 ms slot d5 which would have been output at the beginning of a new frame is not transmitted, and instead an end signal E is transmitted and the carrier is turned off for the rest of the 20 ms period. In this case, the block d6 contains user data so that the carrier is turned on and a new frame Sm_{n+1} is transmitted, beginning with block d6. In this way, although frame synchronisation is not maintained on carrier reactivation, synchronisation is maintained with blocks which represent a fraction of the total frame length, so that the receiver does not need to resychronise to any great extent.

Figure 13 shows an algorithm used by an MIU receiving the transmissions represented by Figure 11, every time a new frame SM is received. At step V10, a new frame is demodulated and decoded. At step V20, the MIU detects whether the frame is followed immediately by an EOD signal. If not, at step V30 the contents of the received frame are output to the DTE 2 or 18, but otherwise the MIU detects at step V40 whether the last byte of the current frame is equal to hex 7E or its bit-shifted versions. If it is equal to one of these, at step V50 this last byte is repeatedly output to the DTE 2, 18 until the next frame is received or the call is cleared; this has the effect of transmitting a continuous series of flags to the DTE. If the result of step V40 is negative, the MIU outputs hex 7E flags continuously to the DTE at step V60 until the next frame is received or the call is cleared.

The algorithms of Figures 9, 12 and 13 are designed specifically to look for an HDLC hex 7E flag, but may be modified to look for any repeating byte entirely filling a frame or block, and to turn the carrier off if the repeating byte is also the last byte in the previous transmitted frame or block. The receiving MIU would then output the repeated byte a number of times corresponding to the period for which the carrier is switched off. Thus, power can be saved by not transmitting repeated user data, as well as repeated flags. The receiving MIU infers that the last byte of the previous frame should be repeated if the carrier is switched off, but must maintain timing synchronisation to calculate the correct number of repetitions. However, since the carrier is switched off for an integral number of blocks or frames, the receiving MIU need only be able to detect the carrier deactivation interval with a resolution of one block or frame, so that the local clock reference of the receiving MIU would be sufficient.

The above embodiments have been described with reference to an 8-bit HDLC protocol, but are applicable to other communications protocols with different idle sequences. For example, in a 16-bit variant of HDLC, the idle flag is hex 7FFE, so the carrier activation algorithm would look for bit-shifted versions of that flag instead. Alternatively, some protocols may use an all-zero or all-one byte (e.g. hex 00 or FF) as an idle flag. In that case, there would be no need to look for bit-shifted versions of the idle flag, but the carrier would be deactivated if a block or frame contained all zeros or all ones. Other

protocols use a repeating sequence of different bytes to indicate an idle state; for example MPEG-4 uses a repeating sequence of a pseudo-random synchronisation sequence and a header. If transmitting data under those protocols, the MIU stores at least the quantity of data from a previous block or frame corresponding to one repeat period of an idle sequence and compares this to the contents of the current block or frame to see if the sequence is repeated throughout the block or frame. Optionally, the MIU's may be operable with more than one protocol, each having a different byte length or flag sequence, and the protocol type is then signalled from the transmitting FIU to the receiving FIU during call set-up so that the parameters of the carrier deactivation algorithms can be set appropriately at the the receiving MIU.

In the embodiments described above, the carrier transmitted by either the LES 10 or the MES 6 can be deactivated; in the former case, satellite power efficiency is improved, while in the latter case, MES battery power is saved. However, it is not essential that carrier activation should be implemented in both directions. For example, carrier activation may be an optional feature of the MES, so long as the LES 10 is able to perform the necessary reception protocols if carrier activation is implemented at the MES.

The present invention is not limited to present or proposed Inmarsat™ satellite services, but may be applied to other satellite data services employing HDLC or other protocols.

In the above embodiments, a carrier is deactivated completely if there is only redundant data to be sent. Alternatively, however, the power level of the carrier could be reduced and optionally a synchronising sequence such as a unique word transmitted at reduced power during the deactivation period; this reduces the power requirements of an MES if implemented on an MES MIU and of a satellite if implemented on an LES MIU. Hence, references herein to 'deactivating' a carrier encompass the continued transmission on a carrier at reduced power while not transmitting any user data or level signalling information.

In the specific description above, the apparatus is illustrated in terms of functional blocks, for ease of explanation. However, these blocks do not necessarily correspond to discrete physical units.

CLAIMS

1. Radio frequency communications apparatus for connection between a source of data and a radio frequency transmitter, the apparatus being arranged to divide said data in sequence into blocks and to compare a series of bits of a predetermined length at the end of a first block with multiple sequential series of bits of said predetermined length comprising a second block, and, if all of said series are equal, inhibiting transmission of said second block.

2. Apparatus as claimed in claim 1, further comprising carrier control means for deactivating or reducing the power level of a carrier transmitted by the radio frequency transmitter for at least approximately a transmission time corresponding to the length of said second block.

3. Apparatus as claimed in claim 1 or 2, further arranged to format the blocks into frames for transmission, each of said blocks being of the same length and each of said frames comprising the same, integral number of said blocks.

4. A method of radio frequency communication, comprising:

dividing data for transmission into blocks in sequence;

comparing a series of bits of a predetermined length at the end of a first block with multiple sequential series of bits of said predetermined length comprising a second block, and

if all of said series are equal, inhibiting transmission of said second block.

5. A method as claimed in claim 4, further comprising deactivating or reducing the power level of a carrier transmitted by the radio frequency transmitter for at least approximately a transmission time corresponding to the length of said second block.

6. A method as claimed in claim 4 or claim 5, further comprising formatting the blocks into frames prior to transmission, each of the blocks being of the same length and each of said frames comprising the same, integral number of said blocks.

7. Communications interface apparatus for connection between a source of data, including user data, and a transmitter, said data having a format in which an absence of user data is indicated by a predetermined bit sequence,

the apparatus being arranged to output said user data to said transmitter for transmission on a modulated radio frequency carrier,

the apparatus being further arranged to compare a series of bits of said data with said predetermined bit sequence, with a plurality of different relative bit alignments, and to control the transmitter to deactivate said carrier if a match is found with any of said bit alignments.

8. Apparatus as claimed in claim 7, arranged to compare said series of bits, having a length equal to that of the predetermined bit sequence, with each of a set comprising said predetermined bit sequence and all bit-shifted permutations thereof.

9. Apparatus as claimed in claim 8, arranged to format said data in a series of constant length frames or blocks for transmission on said carrier, the apparatus being arranged to compare each said sequential series of data bits of one of said frames or blocks and the last said series of data bits of the previous one of said frames or blocks with each of said set, and to control the transmitter to deactivate the carrier such that said one frame or block is not transmitted if all of said compared series are equal to the same one of said set.

10. Apparatus as claimed in any one of claims 7 to 9, wherein said source of data is arranged to modify said user data by inserting at least one additional bit prior to output.

11. Apparatus as claimed in any one of claims 7 to 10, arranged subsequently to reactivate said carrier when no said match is found.

12. A method of carrier deactivation, comprising:

receiving data, including user data, in a format in which an absence of user data is indicated by a predetermined bit sequence, and transmitting said user data on a modulated radio frequency carrier, the method including:

comparing a series of bits of said data with said predetermined bit sequence, with a plurality of different relative bit alignments, and

deactivating said carrier if a match is found with any of said bit alignments.

13. A method as claimed in claim 12, wherein said comparing step comprises comparing said series of bits, having a length equal to that of the predetermined bit sequence, with each of a set comprising said predetermined bit sequence and all bit-shifted permutations thereof.

14. A method as claimed in claim 13, wherein said data is formatted in a series of constant length frames or blocks, the comparing step comprising comparing each said sequential series of data bits of one of said frames or blocks and the last said series of data bits of the previous one of said frames or blocks with each of said set, and deactivating the carrier such that said one

frame or block is not transmitted if all of said compared series are equal to the same one of said set.

15. A method as claimed in any one of claims 12 to 14, wherein said user data is modified by inserting at least one additional bit prior to said receiving step.

16. A method as claimed in any one of claims 12 to 15, further comprising the step of subsequently reactivating said carrier when no said match is found.

17. Communications interface apparatus for connection between a source of data, including both user data and signalling information, and a transmitter, such that said user data is transmitted by said transmitter on a modulated radio frequency carrier,

the apparatus being arranged to receive said data, to detect the presence of repeated signalling information and the absence of user data in said data, and to deactivate said carrier if the number of repetitions of said signalling information is equal to or exceeds a predetermined value, such that excess repetitions are not transmitted.

18. Apparatus as claimed in claim 17, wherein said signalling information is an HDLC line control message.

19. Apparatus as claimed in claim 17, wherein said signalling information is a flow control message.

20. A method of carrier deactivation, comprising:

receiving data, including both user data and signalling information, and transmitting said user data on a modulated radio frequency carrier, the method including:

detecting the presence of repeated signalling information and the absence of user data in said data, and

deactivating said carrier if the number of repetitions of said signalling information is equal to or exceeds a predetermined value, such that said excess repetitions are not transmitted.

21. A method as claimed in claim 20, wherein said signalling information is an HDLC line control message.

22. A method as claimed in claim 20, wherein said signalling information is a flow control message.

23. Satellite communications interface apparatus for connection between a source of data and an earth station transmitter,

the apparatus being arranged to format said data as a series of constant length frames and to selectively output said frames to said transmitter such that said output frames are transmitted on a modulated radio frequency carrier in an SCPC format,

the apparatus being further arranged to detect whether at least an initial portion of each of said frames contains no information or only redundant information, to control the transmitter to deactivate the carrier in response to a positive said detection, to reactivate the carrier in response to a subsequent negative said detection, and to transmit frames subsequent to said reactivation with a timing synchronised with that of frames prior to said deactivation.

24. Apparatus as claimed in claim 23, wherein the apparatus is arranged to detect whether the whole of each of said frames contains no information or only redundant information.

25. A method of satellite carrier activation, comprising:

receiving data, formatting said data as a series of constant length frames, and selectively transmitting said frames on a modulated radio frequency carrier in an SCPC format,

the step of selective transmission comprising detecting whether at least an initial portion of each frame contains no information or only redundant information, and deactivating the carrier such that said portion of the frame is not transmitted,

wherein, after the carrier is deactivated, subsequent frames are transmitted with a timing synchronised with that of frames transmitted prior to said deactivation.

26. A method as claimed in claim 25, wherein the detecting step comprises detecting whether the whole of each of said frames contains no information or only redundant information.

27. A method of transmitting a data burst via satellite to a receiving terminal, comprising:

transmitting the data burst in a format comprising one or more frames having a variable power level modulation, preceded by a preamble having a constant power level.

28. A method as claimed in claim 27, wherein the power level of said preamble is approximately equal to the average power level of said one or more frames.

29. A data burst signal comprising a frequency carrier modulated by a preamble having a constant power level, followed by one or more data frames having a variable power level.

30. A satellite earth station including apparatus as claimed in any one of claims 1 to 3, 7 to 11, 17 to 19, 23 and 24.

31. A method substantially as herein described with reference to Figures 11a to 11c of the drawings.

32. A signal substantially as herein described with reference to Figure 11c of the accompanying drawings.

33. A method substantially as herein described with reference to Figure 12 of the drawings.

34. A method substantially as herein described with reference to Figure 13 of the accompanying drawings.

The Patent Office
33
INVESTOR IN PEOPLE

Application No:	GB 9904575.9	**Examiner:**	Gareth Griffiths
Claims searched:	1-6	**Date of search:**	12 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4L (LDGX, LDH, LDRS, LECSV, LECSX, LECTP, LETXX)

Int Cl (Ed.6): H03G 3/20, 3/30, H04B 7/005, 7/155, 7/185, 7/212, 7/26, H04Q 7/22, 7/32

Other: Online Databases: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US5239557 (DENT)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

(12) UK Patent Application (19) GB (11) 2 336 508 (13) A

(43) Date of A Publication 20.10.1999

(21) Application No 9904575.9

(22) Date of Filing 26.02.1999

(30) Priority Data
(31) 9804640 (32) 04.03.1998 (33) GB
(31) 9804639 (32) 04.03.1998

(71) Applicant(s)
Inmarsat Limited
(Incorporated in the United Kingdom)
99 City Road, LONDON, EC1Y 1AX, United Kingdom

(72) Inventor(s)
Howard Ray Feldman
Siu Wah Wong

(74) Agent and/or Address for Service
R G C Jenkins & Co
26 Caxton Street, LONDON, SW1H 0RJ,
United Kingdom

(51) INT CL[6]
H04Q 7/32 // H04B 7/185 7/26

(52) UK CL (Edition Q)
H4L LECTP L1H8A

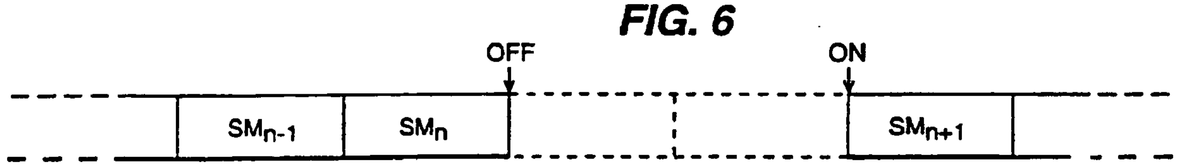
(56) Documents Cited
US 5239557 A

(58) Field of Search
UK CL (Edition Q) H4L LDGX LDH LDRS LECSV LECSX LECTP LETXX
INT CL[6] H03G 3/20 3/30, H04B 7/005 7/155 7/185 7/212 7/26, H04Q 7/22 7/32
Online Databases: WPI, EPODOC, JAPIO

(54) Abstract Title
Data carrier deactivation in absence of user data

(57) In a radio communications system in which data is transmitted on a modulated radio frequency carrier, the carrier is switched off when no data is available for transmission. If repeated signalling information is required to be transmitted, only a predetermined number of repeats are transmitted before the carrier is switched off. In one embodiment a bit sequence at the end of a first data block is compared with multiple sequences from a second block and if all sequences are equal, transmission of the second block is inhibited. In another embodiment data input for transmission is compared with a predetermined bit sequence. If a match is found for any relative bit alignment, this indicates an idle state (absence of user data) and the carrier is switched off. When more user data is received the carrier is switched on and frames are transmitted in synchronisation with the timing of frames transmitted before carrier deactivation. After carrier reactivation a constant power preamble may be transmitted to assist in level control in the transmitter. In a satellite SCPC system satellite power efficiency is improved and mobile earth station battery power is saved.

FIG. 6



GB 2 336 508 A

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977

CV 06067

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 994 579 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.04.2000 Bulletin 2000/16

(51) Int. Cl.^{7}: H04B 7/26

(21) Application number: 99119925.8

(22) Date of filing: 11.10.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 12.10.1998 US 169875

(71) Applicant: TRW Inc.
Redondo Beach, California 90278 (US)

(72) Inventor: Wright, David A.
Solana Beach, CA 92075 (US)

(74) Representative:
Schmidt, Steffen J., Dipl.-Ing.
Wuesthoff & Wuesthoff,
Patent- und Rechtsanwälte,
Schweigerstrasse 2
81541 München (DE)

(54) Common downlink frame for differing coding rates

(57) A method is provided for organizing a plurality of cells into a fixed size frame for transmission in the downlink of a processing satellite (12) to at least one of a plurality of earth terminals (14), comprising the steps of: (a) determining an inner coding rate (22) for a first set of data cells (20); (b) forming a group of codewords by applying an outer code (24) to the first set of data cells (20), such that the number of codewords being proportional to the inner coding rate; (c) entering the group of codewords row wise (26) into an interleaving array; and (d) applying an inner code column wise (28) to the group of codewords, thereby forming a fixed size frame body (30). More specifically, the interleaving area includes a plurality of columns and a plurality of rows, such that the plurality of columns is equivalent to a block size of the outer code and the plurality of rows is equivalent to the number of codewords multiplied by the number of bits for each codeletter in the codewords and then divided by the inner coding rate.

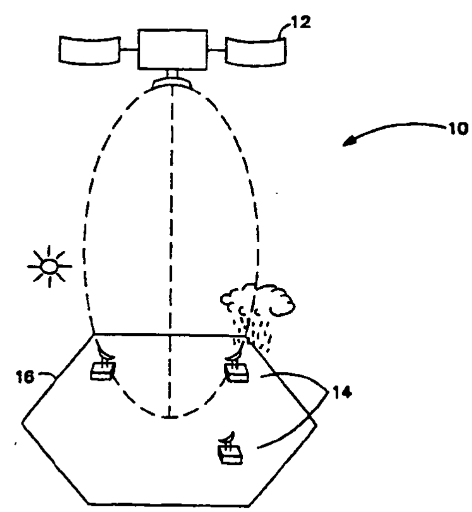


FIG. 1

EP 0 994 579 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates generally to adaptive forward error correction coding in a data communication system and, more particularly, to a method of organizing data cells into a fixed size frame for transmission in the downlink from a processing satellite to a plurality of earth terminals.

2. Discussion of the Related Art

[0002] A downlink transmission from a spot beam processing satellite is typically a single access time division multiplexed (TDM) stream that is organized into discrete units known as frames. Generally, these frames encapsulate information which has been processed (at the satellite) to add redundancy for error correction at the earth terminal. In processing satellites, the forward error correction coding scheme typically applies an inner code and an outer code separated by an interleaver. To provide additional margin for weather effects and/or compensate for variations in gain across an antenna footprint, the rate used for error control coding may be varied from frame to frame.

[0003] To avoid complex processing in the transmission and reception of these frames, it is desirable that the size of the frame be invariant to changes in coding rates, otherwise more complex circuitry may be required to handle differently coded frames. In addition, variable size downlink frames present complications for the earth terminal electronics in deriving uplink synchronization from the downlink transmissions.

SUMMARY OF THE INVENTION

[0004] In accordance with the present invention, a method is provided for organizing a plurality of data cells into a fixed size frame for transmission in the downlink of a processing satellite, comprising the steps of: (a) determining an inner coding rate for a first set of data cells; (b) forming a group of codewords by applying an outer code to the first set of data cells, such that the number of codewords is proportional to the inner coding rate; (c) entering the group of codewords row wise into an interleaving array; and (d) applying an inner code column wise to the group of codewords, thereby forming a fixed size frame body.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Other objects and advantages of the present invention will be apparent to those skilled in the art upon reading the following detailed description and upon reference to the drawings in which:

Figure 1 is a diagram illustrating a typical satellite data communication system in accordance with the present invention;

Figure 2 is a diagram illustrating the downlinking method of the present invention; and

Figure 3 is detailed dataflow diagram showing the downlinking method of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0006] While the invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those having ordinary skill in the art and access to the teachings provided herein will recognize additional modifications, applications and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

[0007] A typical satellite communication system 10 is depicted in Figure 1. Communication system 10 includes a spot beam processing satellite 12 which completes a virtual circuit connection between any two of a plurality of earth terminals 14. Generally, information is uplinked from a earth terminal 14 to the satellite 12 which in turn downlinks the information to a receiving earth terminal 14. For an uplink transmission, the satellite frequency domain is divided into narrow frequency channels such that each channel is used in a time-division multiple access (TDMA) mode, known to those skilled in the art. At the satellite 12, uplink transmissions are demodulated, decoded and unpacked to recover the self addressed, fixed length data cells. These data cells are switched to queues for the appropriate downlink and coding rate, and then downlinked to the appropriate earth terminal 14. As will also be apparent to one skilled in the art, a single access time division multiplexed (TDM) stream is typically used to downlink information to receiving earth terminal 14.

[0008] Downlink transmissions from processing satellite 12 often use various forward error correction coding schemes for error control. Generally, coding schemes fall into two main categories: block codes and convolutional codes. Decoding schemes for block codes generally use algebraic procedures, based on properties of the code structure, and involve solving sets of algebraic equations; Reed-Solomon codes are commonly used block codes. For convolutional codes, the most common decoding scheme is the maximal-likelihood Viterbi algorithm; basically a dynamic programming technique. Concatenated coding is one well known technique for combining the error correcting benefits of block codes with the benefits of convolutional codes.

[0009] Furthermore, processing satellite 12 typically operates at frequencies in the Ka band (e.g., on the order of 20 gigahertz). At these frequencies, rain

produces a significant amount of attenuation in the downlink transmissions. Therefore, it is necessary to provide substantial link margin to permit transmission during unfavorable weather conditions. Furthermore, an antenna coverage pattern 16 for such spot beam satellites often exhibits substantial variation in gain across its antenna footprint. In particular, the amount of gain drops moving from the center to the outer limit of an antenna beam.

[0010] To provide additional margin for weather effects and/or compensate for variations in gain across an antenna footprint, the rate used for error control coding may be varied from frame to frame. This is commonly referred to as adaptive forward error control. For example, one frame may be coded with a high coding rate ("light" coding) for downlink transmissions to earth terminals located at mid beam and/or under clear sky; whereas other frames use a lower coding rate ("heavy" coding) for downlinking to earth terminals located near the outer limit of an antenna beam and/or experiencing rain. As a result, a frame containing "lightly" coded information has less redundancy than a frame containing "heavy" coded information. In order to implement adaptive error coding, satellite 12 includes means for determining which coding rate is to be used in forming the next downlink frame. Such determination is based on parameters supplied to the satellite from other portions of the system and is not explicated herein.

[0011] To avoid complex processing in the transmission of downlink frames, it is desirable that the size of these frames be invariant to changes in coding rates. In accordance with the present invention, communication system 10 employs a method of organizing a plurality of data cells into a fixed size frame for transmission in the downlink of a processing satellite. A diagram illustrating the method of the present invention is shown as Figure 2.

[0012] First, an inner coding rate is determined 22 for the next frame to be formed. A group of codewords are then formed by applying 24 the outer code to a set of data cells 20, such that the number of codewords formed is based on the inner coding rate. The information content of each such codeword includes a number of data cells (sufficient to fill the codeword) drawn from a buffer which queues data cells according to their selected coding rate.

[0013] A rectangular array is used for interleaving between the codes. To format the array 26, the group of codewords are placed row wise into the interleaving array, partially filling it. Next, the contents of the array are expanded by applying the inner code 28 to the columns of this array. At the completion of the inner coding, a fixed size downlink frame 30 is formed, regardless of the coding rate.

[0014] More specifically, concatenated coding in the present invention applies an "outer" code (e.g., a block code) and an "inner" code (e.g., convolutional code) to each downlink frame. Each frame includes a body containing payload information as well as a header and/or trailer for use in overhead transmission functions. It is this payload information that is subject to error correction coding. A (N, K, v) Reed-Solomon ("outer") code is applied to the payload information received from the satellite's ATM-based switching system. Since ATM cells are byte organized, the Reed-Solomon code is also byte organized. Therefore, payload information is preferably received in (K=) 212 byte data cells (which corresponds to four ATM cells) and then translated into (N=) 236 byte Reed-Solomon codewords, where each codeletter of the code is a binary (v=) 8-tuple.

[0015] After the coding rate for a particular frame has been determined, rectangular interleaving between the outer and inner code is used to generate each downlink frame. Referring to Figure 3, an interleave area is defined as a fixed size rectangular array 40 (having N columns and n*v rows) -for storing N*n*v bits of payload information. It should be noted that the number of columns (N) in array 40 corresponds to a multiple of the block size for the outer code (e.g., N=236).

[0016] Based on the inner coding rate, the rectangular array is formatted with Reed-Solomon codewords. For a convolutional code having a coding rate of k(i)/n, k(i) codewords are entered into array 40, where k(i) and n are integers with k(i) <= n. Since the Reed-Solomon codewords are based on codeletters of "v" bits (e.g. preferably 8 bits), these codewords occupy k(i)*v rows of the array (i.e., each outer codeword occupies v bits of a column). Next, the contents of the array are presented column-wise to the inner encoder which expands the size of each column to n*v bits. In this way, the resultant array has a fixed size of N*n*v bits, regardless of the inner code rate.

[0017] For instance, to generate a light coded frame, k(il) codewords (e.g., 6 codewords) are entered into an array 42. The contents of array 42 are then expanded by applying an inner code rate of k(il)/n (e.g., 6/8) to each column of array 42. In this way, a light coded frame 46 is comprised of 236*6*(8/6)*8 or 15,104 bits of payload information. A similar approach is used to form a heavy coded frame, except that to begin the process only k(ih) codewords (e.g., 3 codewords) are entered into an array 44. Although fewer outer codewords are initially entered into the interleaver, frame 46 is completely filled after the heavy inner code rate of k(ih)/n (e.g., 3/8) is applied to each column. Accordingly, heavy coded frame 46 is also comprised of 236*3*(8/3)*8 or 15,104 bits of payload information.

[0018] Therefore, regardless of the inner coding rate, a fixed size array 46 having N*n*v bits of payload information is formed at the completion of the concatenated coding process. Array 46 is commonly referred to as the body of a frame. In the preceding discussion, reference has only been made to either light or heavy coding. It is envisioned that the present invention can accept many distinct coding rates, so long as n is the

same and the inner code rate is held constant within a given frame.

[0019] To complete a downlink transmission frame 50, some overhead information is appended to the body. Overhead information is of a fixed length in the form of a header 52 (prepended at column 1) and a trailer 54 (postpended at column N). The header 52 contains a fixed synch pattern which is used to delineate the frame within the TDM stream and an indicator as to the coding rate associated with the frame. It should be noted that the synch pattern also serves to eliminate the four way ambiguity that arises with QPSK TDM streams. Other information (e.g., frame number) may also be included in frame header 52. The trailer 54 may contain the "tailoff" bits from the convolutional encoding process and is sized to accommodate the longest tailoff required for the various inner coding rates to be accommodated with a fixed length frame. As a result, the overhead structure is common to each frame and the frame length is fixed for all coding rates.

[0020] It should be appreciated that the downlinking method of the present invention provides commonality of length and structure for each frame, and thus simplifies the electronics required to interleave and form frames at the satellite. Simplified electronics can also then be used to delineate the frames from the TDM stream, expunge quadrant ambiguity, and control variable rate decoding at the earth terminal. Due to the high regularity associated with the frames, this downlinking approach also increases reliability of downlink synchronization and simplifies the uplink synchronization procedure for earth terminals.

[0021] The foregoing discloses and describes merely exemplary embodiments of the present invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that various changes, modifications and variations can be made therein without departing from the spirit and scope of the present invention.

Claims

1. A method of organizing a plurality of data cells into a fixed size frame for transmission in the downlink of a processing satellite to at least one of a plurality of earth terminals in a satellite communication system, comprising the steps of:

    determining a coding rate for a first set of data cells, said coding rate associated with a first code;
    applying a second code to said set of data cells to form a group of coded blocks, such that the number of coded blocks is based on said coding rate;
    formatting an interleaver area with said group of coded blocks; and
    applying a first code to said group of coded blocks using said coding rate, thereby forming a fixed size frame.

2. The method of Claim 1 wherein the step of applying a first code further comprises utilizing a convolutional code as said first code.

3. The method of Claim 1 wherein the step of applying a second code further comprises utilizing a Reed-Solomon code as said second code.

4. The method of Claim 1 further comprising the step of appending frame overhead data to said first frame prior to transmission in the downlink of the processing satellite, said frame overhead data including an indication of said coding rate.

5. The method of Claim 1 comprising addressing each data cell of said first set of data cells independently to one or more of the plurality of earth terminals.

6. The method of Claim 1 further comprising transmitting said fixed size frame to a first earth terminal and basing said coding rate on a characteristic of said first earth terminal.

7. The method of Claim 6 further comprising selecting said characteristic of said first earth terminal from at least one of the signal propagation associated with said first earth terminal and the location of said first earth terminal within the antenna coverage of the satellite.

8. The method of Claim 1 wherein the step of formatting an interleaver area further comprises providing a rectangular array having a plurality of columns and a plurality of rows, such that said plurality of columns being equivalent to a block size of said second code and said plurality of rows being equivalent to the number of coded blocks multiplied by the number of bits for each codeletter and then divided by said coding rate.

9. The method of Claim 8 wherein the step of applying a first code further comprises expanding said coded blocks in each of said plurality of columns of said rectangular array.

10. The method of Claim 1 further comprising the steps of:

    transmitting said fixed size frame to a first earth terminal;
    determining a second coding rate for a second set of data cells;
    applying said second code to said second set of data cells to form a second group of coded blocks, such that the number of coded blocks

being based on said second coding rate;

formatting said interleaver area with said second group of coded blocks;

applying said first code to said second group of coded blocks using said second coding rate, thereby forming a second fixed size frame; and transmitting said second fixed size frame to a second earth terminal.

11. A method of organizing a plurality of data cells into a fixed size frame for transmission in the downlink of a processing satellite to at least one of a plurality of earth terminals, comprising the steps of:

determining an inner coding rate for a first set of data cells;

forming a group of codewords by applying an outer code to said set of data cells, such that the number of codewords being proportional to said inner coding rate;

entering said group of codewords row wise into an interleaving array; and

applying an inner code column wise to said group of codewords, thereby forming a fixed size frame body.

12. The method of Claim 11 further comprising the step of appending frame overhead data to said fixed size frame body prior to transmission in the downlink of the processing satellite, said frame overhead data including an indication of said inner coding rate.

13. The method of Claim 11 comprising addressing each cell of said first set of data cells independently to one or more of the plurality of earth terminals.

14. The method of Claim 11 wherein the step of forming a group of codewords further comprises utilizing a Reed-Solomon code as said outer code.

15. The method of Claim 11 wherein the step of applying an inner code further comprises utilizing a convolutional code as said inner code.

16. The method of Claim 11 further comprising transmitting said fixed size frame to a first earth terminal and basing said inner coding rate on a characteristic of said first earth terminal.

17. The method of Claim 16 further comprising selecting said characteristic of said first earth terminal from at least one of the signal propagation associated with said first earth terminal and the location of said first earth terminal within the antenna coverage of the satellite.

18. The method of Claim 11 wherein the step of formatting an interleaver array further comprises providing a rectangular array having a plurality of columns and a plurality of rows, such that said plurality of columns being equivalent to a block size of said outer code, and said plurality of rows being equivalent to the number of codewords multiplied by the number of bits for each codeletter in said codewords and then divided by said inner coding rate.

19. The method of Claim 11 further comprising the steps of:

transmitting said fixed size body to a first earth terminal;

determining a second coding rate for a second set of data cells;

applying said outer code to said second set of data cells to form a second group of codewords, such that the number of codewords being based on said second coding rate;

formatting said interleaver area with said second group of codewords;

applying said inner code to said second group of codewords using said second coding rate, thereby forming a second fixed size frame body; and

transmitting said second fixed size frame body to a second earth terminal.

20. A method of organizing a plurality of data cells into a fixed size frame for transmission in the downlink of a processing satellite to at least one of a plurality of earth terminals, comprising the steps of:

determining an inner coding rate for a first set of data cells;

forming a group of codewords by applying an outer code to said set of data cells, such that the number of codewords being proportional to said inner coding rate;

entering said group of codewords row wise into an interleaving array, said interleaving array having a plurality of columns and a plurality of rows, such that said plurality of columns being equivalent to a block size of said outer code and said plurality of rows being equivalent to the number of codewords multiplied by the number of bits for each codeletter in said codewords and then divided by said inner coding rate; and

applying an inner code column wise to said

group of codewords, thereby forming a fixed size frame body.

21. A data communication system for transmitting a fixed size frame in a downlink from a processing satellite to at least one of a plurality of earth terminals, comprising:

    a means for determining an inner coding rate for downlinking a set of data cells to a first earth terminal, said inner coding rate being based on a characteristic of said first earth terminal;
    a first encoder for forming a group of codewords by applying an outer code to said set of data cells, such that the number of codewords being proportional to said inner coding rate;
    a means for entering said group of codewords row wise into an interleaver array; and
    a second encoder for applying an inner code column wise to said group of codewords, thereby forming a fixed size frame.

22. The data communication system of Claim 21 further comprises a means for appending frame overhead data to said fixed size frame prior to transmission in the downlink of the processing satellite, said frame overhead data including an indication of said inner coding rate.

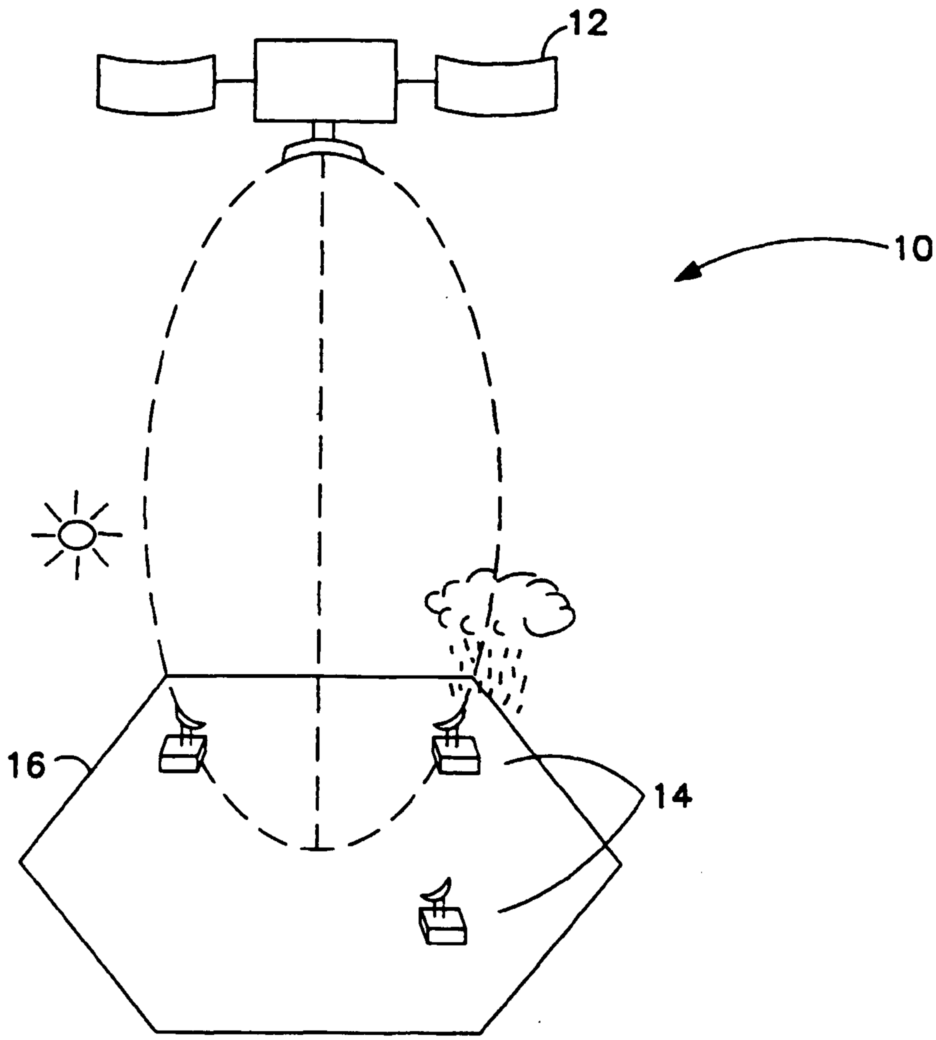


FIG. 1

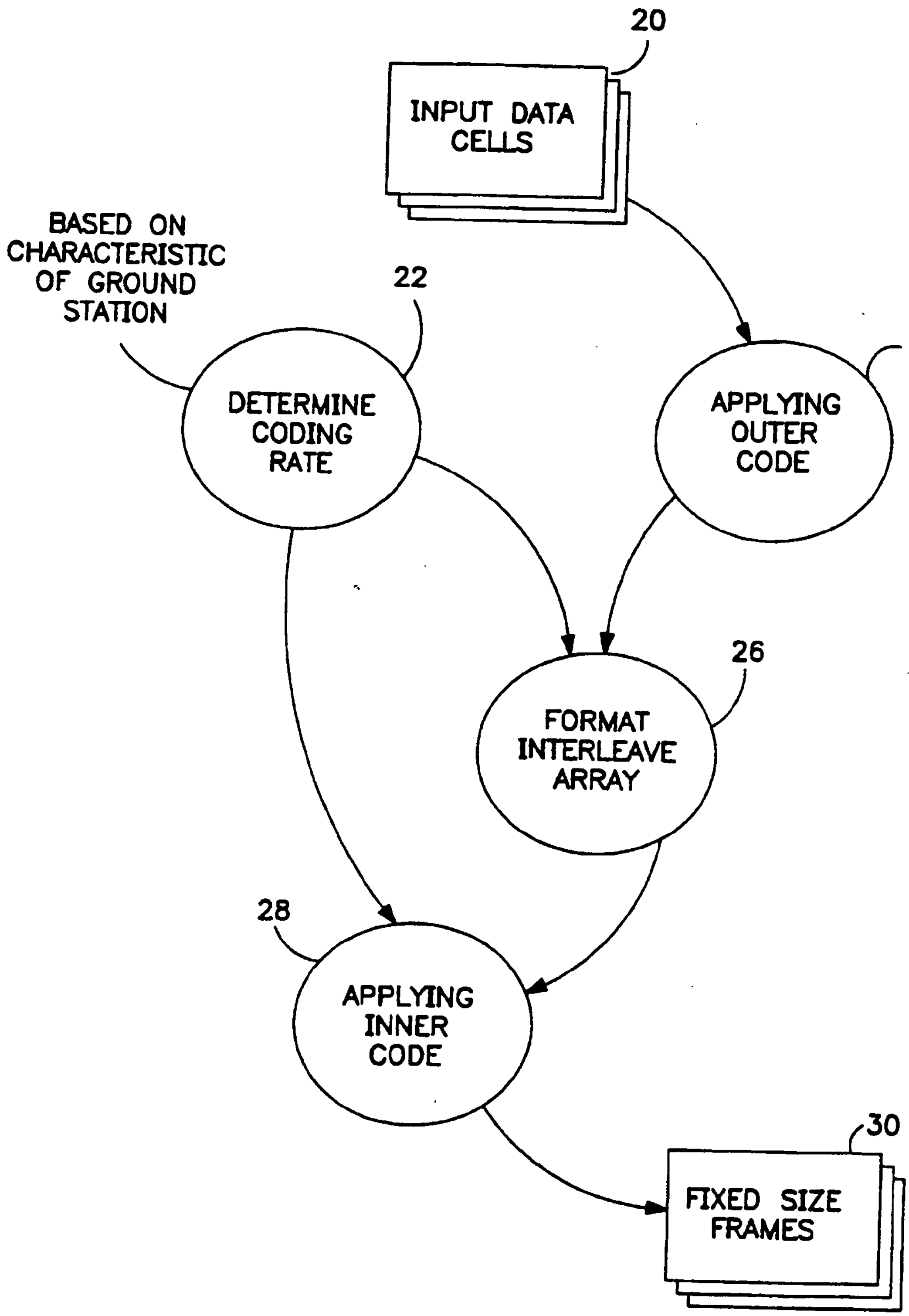

20
INPUT DATA CELLS
BASED ON CHARACTERISTIC OF GROUND STATION
22
DETERMINE CODING RATE
24
APPLYING OUTER CODE
26
FORMAT INTERLEAVE ARRAY
28
APPLYING INNER CODE
30
FIXED SIZE FRAMES

FIG. 2

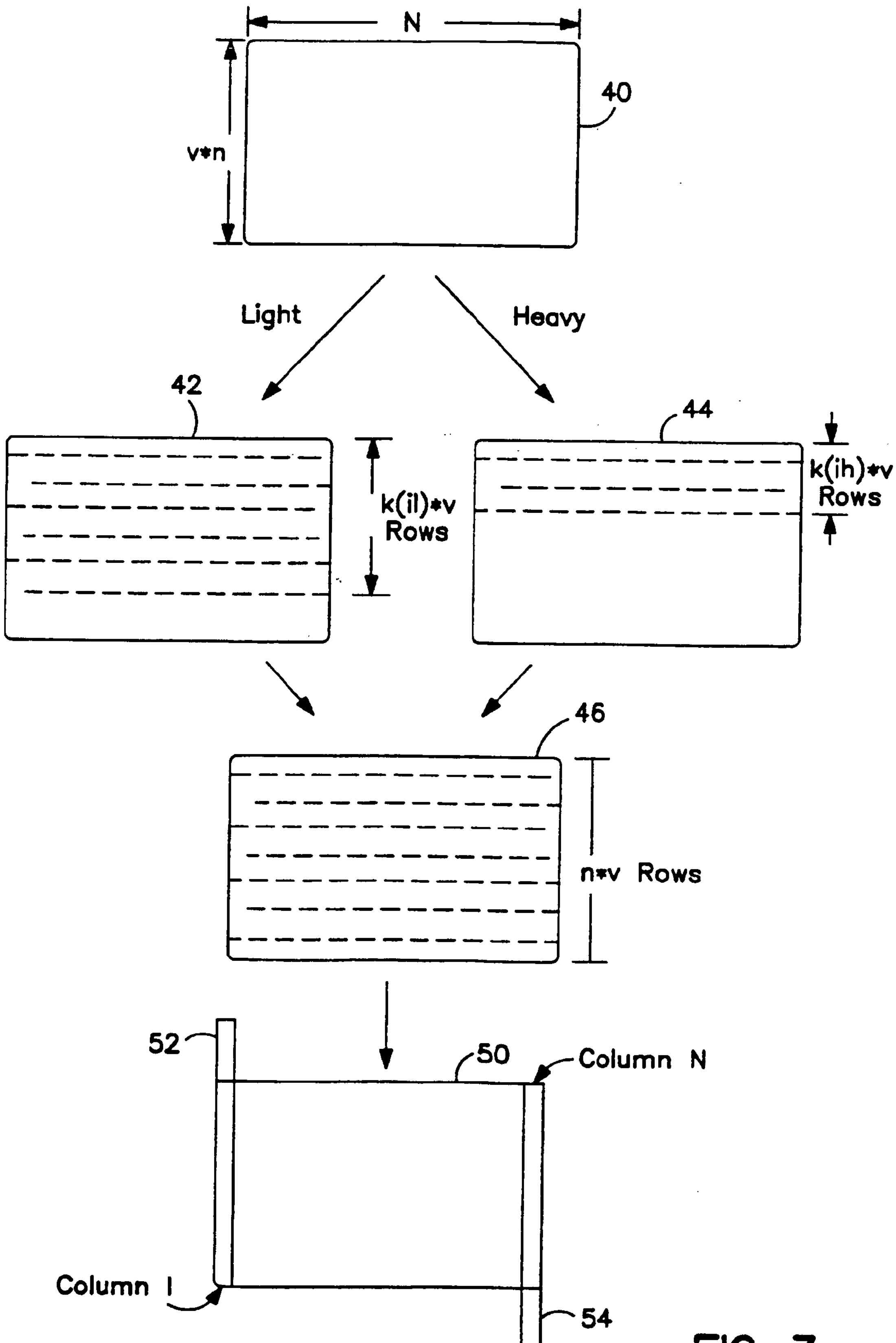

N
40
v*n
Light
Heavy
42
44
k(il)*v
Rows
k(ih)*v
Rows
46
n*v Rows
52
50
Column N
Column I
54

FIG. 3

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 994 579 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
06.08.2003 Bulletin 2003/32

(43) Date of publication A2:
19.04.2000 Bulletin 2000/16

(21) Application number: 99119925.8

(22) Date of filing: 11.10.1999

(51) Int Cl.7: H04B 7/26, H04B 7/185, H04L 1/00, H03M 13/35

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 12.10.1998 US 169875

(71) Applicant: TRW Inc.
Redondo Beach, California 90278 (US)

(72) Inventor: Wright, David A.
Solana Beach, CA 92075 (US)

(74) Representative: Schmidt, Steffen J., Dipl.-Ing.
Wuesthoff & Wuesthoff,
Patent- und Rechtsanwälte,
Schweigerstrasse 2
81541 München (DE)

(54) Common downlink frame for differing coding rates

(57) A method is provided for organizing a plurality of cells into a fixed size frame for transmission in the downlink of a processing satellite (12) to at least one of a plurality of earth terminals (14), comprising the steps of: (a) determining an inner coding rate (22) for a first set of data cells (20); (b) forming a group of codewords by applying an outer code (24) to the first set of data cells (20), such that the number of codewords being proportional to the inner coding rate; (c) entering the group of codewords row wise (26) into an interleaving array; and (d) applying an inner code column wise (28) to the group of codewords, thereby forming a fixed size frame body (30). More specifically, the interleaving area includes a plurality of columns and a plurality of rows, such that the plurality of columns is equivalent to a block size of the outer code and the plurality of rows is equivalent to the number of codewords multiplied by the number of bits for each codeletter in the codewords and then divided by the inner coding rate.

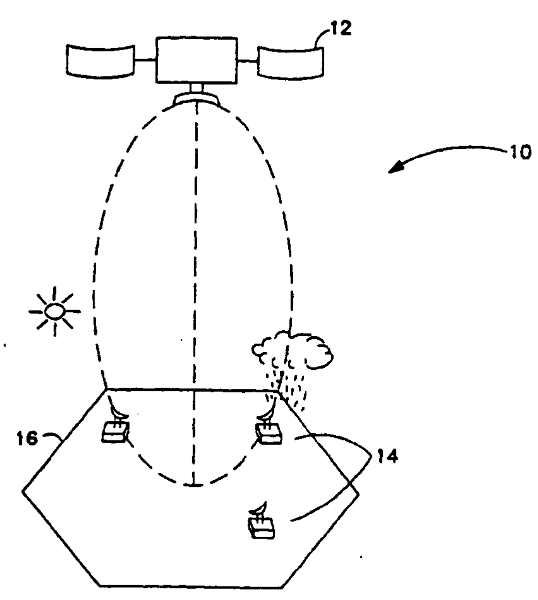


FIG. 1

EP 0 994 579 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 9925

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	EP 0 772 317 A (HUGHES AIRCRAFT CO) 7 May 1997 (1997-05-07) * column 2, line 3 - line 13 * * column 2, line 23 - line 32 * * column 5, line 14 - line 29 * * column 6, line 30 - column 7, line 25; figure 4 * ---	1-22	H04B7/26 H04B7/185 H04L1/00 H03M13/35
A	MATSUOKA H ET AL: "ADAPTIVE MODULATION SYSTEM WITH VARIABLE CODING RATE CONCATENATED CODE FOR HIGH QUALITY MULTI-MEDIA COMMUNICATION SYSTEMS" IEEE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 46, 28 April 1996 (1996-04-28), pages 487-491, XP000594323 ISBN: 0-7803-3158-3 * paragraph [002C]; figure 4 * ---	1-22	
A	EP 0 797 327 A (LUCENT TECHNOLOGIES INC) 24 September 1997 (1997-09-24) * column 3, line 13 - line 33 * -----	1,11,20, 21	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04B H04L H03M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 June 2003	Sorrentino, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 11 9925

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-06-2003

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0772317	A	07-05-1997	EP	0772317 A2	07-05-1997
			NO	964705 A	07-05-1997
EP 0797327	A	24-09-1997	US	5828677 A	27-10-1998
			CA	2197131 A1	21-09-1997
			EP	0797327 A2	24-09-1997
			JP	10022984 A	23-01-1998

For more details about this annex : see Official Journal of the European Patent Office, No 12/82